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Title1

Water Accounting for Krishna Basin

Title2

Stream Flow Modeling of a part of Subarnarekha River Basin using Swat Model

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CERTIFICATE

This is to certify that **Ms. Monamee Das**, M.Sc. final year student of Bharati Vidyapeeth Deemed University - Institute of Environment Education and Research, Pune, under the guidance of **Dr. Sharad Kumar Jain**, has successfully completed his internship and worked on two short projects, title 1: **"Stream Flow Modeling of a part of Subarnarekha River Basin using Swat Model"** & title 2: "**Water Accounting for Krishna Basin**" in partial fulfilment of the Master Degree in Geoinformatics during the academic year 2016-2017.

The work has been completed to our satisfaction and standards. The said Internship Report has not been submitted for any other degree or diploma and any such material which has been obtained from other source has been acknowledged in the Report.

1.8.2017

Monamee Das
M.sc. Geoinformatics
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1/8/17

Dr. Sharad Kumar Jain
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Demographic change analysis in sub basins of River Krishna

WATER ACCOUNTING FOR KRISHNA BASIN

Internship report

Submitted by

MONAMEE DAS

For the partial fulfillment of the

Degree of M.Sc. in GEOINFORMATICS

Submitted to
Bharati Vidyapith Institute of Environmental Research and Education
2017

1. INTRODUCTION

1.1 Water Accounting for Krishna basin

The project is upon "Water Accounting for Krishna basin". It includes climatic parameters as well as social parameters also. For climatic parameters rainfall are calculated and presented as sub basin wise map representation. In topographic parameters Digital Elevation Model, land use land cover map are made. Falcon mark Water Stress indicator and Water Consumption Index are done. Some work of this hole is done by me. In the social parameters population has been taken as an indicator of the change of the social structure over the river basin area. Change in population affects the water resource use, so it is a very important parameter. From the census report of 1991, 2001 and 2011 the change in the sub basin wise population pattern has been calculated and represented. Firstly population data is downloaded on a district basis, and then it is calculated sub basin wise. Finally a graphical representation is made to show the changing rate of demography in the sub basins of Krishna River. From USGS Earth Explorer ASTER DEM is downloaded and a slope map is prepared. Land use land cover image was provided by them which I make a map for a better representation. As NIH provides me the water availability data and I calculated the decadal population, from these data Falcon mark Water Stress Index is calculated for the year 2001 and 2011. Finally a graphical representation of the index is prepared.

1.2 Krishna River

The Krishna River is the fourth biggest river in terms of water inflows and river basin area in India, after the Ganga, Godavari and Bramhaputra. The river is almost 1300 kilometers long. The river is also called Krishnaveni. It is major source of irrigation for Maharashtra, Karnataka, Telengana and Andhra Pradesh.

The Krishna River originates in the Western Ghats near Mahabaleshwar at an elevation of about 1,300 metres, in the state of Maharashtra in central India. It is one of the longest rivers in India. The Krishna River is around 1,300 km in length. The Krishna river's source is at Mahabaleswar near the Jor village in the extreme north of Wai Taluka, Satara District, Maharashtra in the west and empties into the Bay of Bengal at Hamasaladeevi (near Koduru) in Andhra Pradesh, on the east coast. It flows through the state of Karnataka before entering Telangana State. Vijayawada is the largest city on the River Krishna.The total basin area of Krishna River is divided into 12 sub basins. They are named as from K-1 to K-12.Different sub basins have different topography, soil characteristics, different area different water potentiality and different demographic characteristics also.

2. Objectives

The aim of the work is to analyze demographic changes in throughout the Krishna basin. As we all know that there is a scarcity of fresh water everywhere, and in India also there are so many problems are occurring now days due to lack of fresh and unpolluted water resources and its distribution. To meet this aim population data of three census years are downloaded and compared.

Objectives

1. To calculate sub basin wise population of three census years.

2. To make a graphical representation of demographic change in sub basins of Krishna River.

3. Download ASTER DEM and make slope map from that.

4. Making map of Land Use & Land Cover from given classified image provided by NIH (source: Indian Council of Agricultural Research).

5. Making Falcon mark Water Stress Index from provided water availability data.

2.1 Data sources and Tools Used in the Study

The following tools are used to set up the model and load the input database.

Table no 1. *Showing the description of data sources and tools*

SL. No.	Data sources and Tools Used	Description
1	Census data (http://www.censusindia.gov.in)	District wise Decadal population data
2	Microsoft Office Excel 2007	Data Preparation
3	Arc GIS 9.3	Preparation sub basin wise population from district wise population data
4	USGS Earth Explorer	ASTER DEM of 30m
5	Land Use & Land Cover map	Indian Council of Agricultural Research, New Delhi
6	NIH	Water Availability (MCM), calculation of FWSI

Source: *Own draft*

3. STUDY AREA

3.1Location

This study is done over Krishna River. The study area (Fig no.1) situated in the latitude range of 13°10′ to 19°22′ N and longitude 73°17′ to 81°9′ E with an elevation of 4 m to 1189 m above mean sea level covering an area about 254750.14 sq. km and it covers the state of Maharashtra, Andhra Pradesh and Karnataka.

3.2Krishna River

The Krishna River is the fourth biggest river in terms of water inflows and river basin area in India, after the Ganga, Godavari and Bramhaputra. The river is almost 1300 kilometers long. The river is also called Krishnaveni. It is major source of irrigation for Maharashtra, Karnataka, Telengana and Andhra Pradesh.

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It causes heavy soil erosion during the monsoon floods. It flow fast and furious, often reaching depths of over 75 feet (23 m). Ironically, there is a saying in Marathi: "Shant vaahate Krishnamaai" which means "quiet flow Krishna". This term is used to describe that a person should be as quiet as Krishna.

3.3Tributaries

The largest tributary of the Krishna River is the Tungabhadra River with a drainage basin measuring 71,417 km^2 (27,574 sq mi), running for about 531 km (330 mi), but the longest tributary is the Bhima River, which makes a total run of 861 km (535 mi) and has an equally large drainage area of 70,614 km^2 (27,264 sq mi).

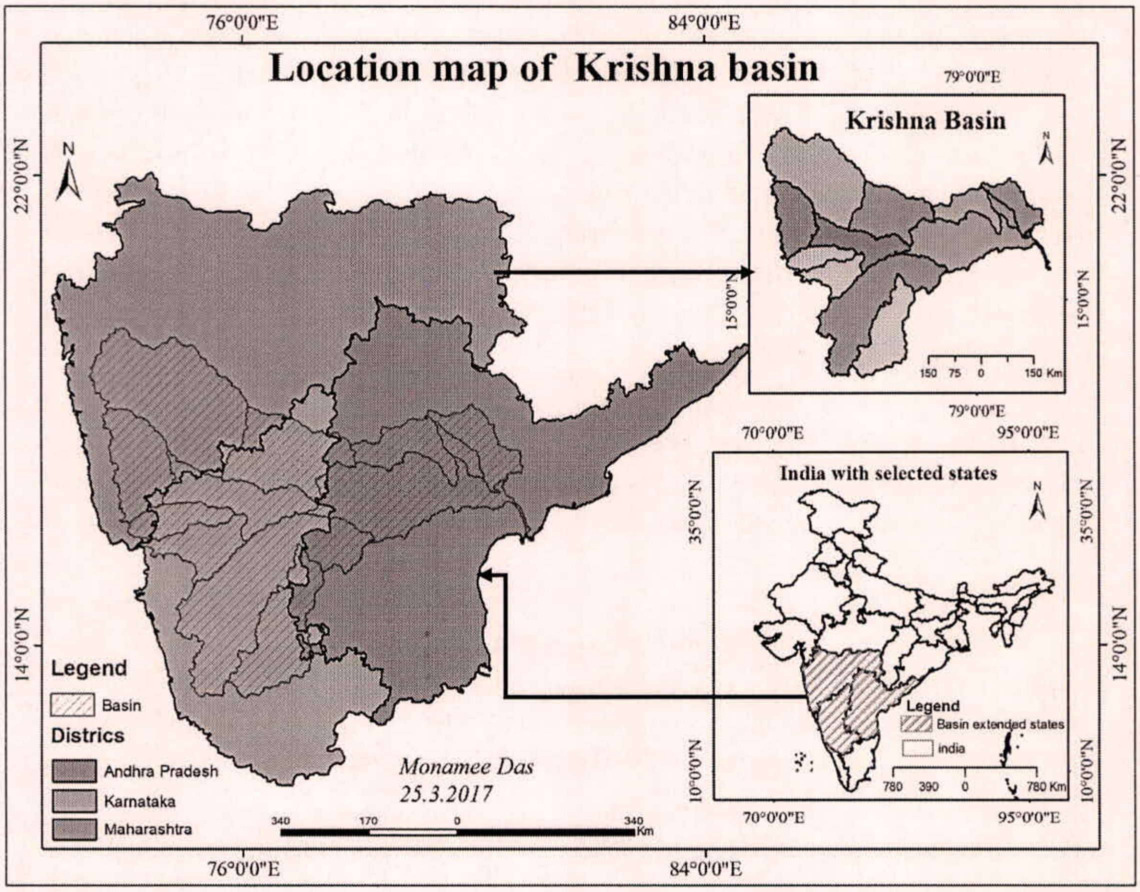
There are four rivers that join the Krishna at a confluence known as Preeti Sangam, or "Lover's Meeting Point" in the Satara District. These are Venna River, Urmodi River, Tarli River and Koyna River.

Three tributaries meet Krishna River near Sangli. These places are considered very holy. It is said that Lord Dattatreya spent some of his days at Audumber on the banks of river Krishna. Sangameswaram of Kurnool district in Andhra Pradesh is a famous pilgrim center for Hindus where Tungabhadra and Bhavanasi rivers join the Krishna River. The Sangameswaram temple is now drowned in the Srisailam reservoir and visible for devotees only during summer when the reservoir's water level comes down.

3.4Sub basins of Krishna

The total basin area of Krishna River is divided into 12 sub basins. They are named as from K-1 to K-12.Different sub basins have different topography, soil characteristics, different area different water potentiality and different demographic characteristics also. A detail description of sub basins is given below in the table no 7.

Figure 1: *Study area map of Krishna River basin*



Source: *Own draft*

Table2. *Salient features of the basin*

Sl no.	**Feature**	**Description**
1	Basin Extent	73° 17' to 81° 9' E 13° 10' to 19° 22' N
2	Area (Sq.km)	a) 254750.14 (GIS based calculated) b) 258948 (Reported Area)
3	States in the basin	Karnataka (43.83%), Andhra Pradesh (29.81%) and Maharashtra (26.36%)
4	Districts (Census 2011)	47
5	Average Annual Rainfall (mm)	859.11
6	Average Annual Maximum Temperature (o C)	32.14
7	Average Annual Minimum Temperature (o C)	20.52
8	Total Population	66341683
9	Highest Elevation (m)	1903
10	Number of Watersheds	391
11	Highest Dam	Srisailam (N.S.R.S.P) Dam -145m
12	Longest Dam	Narayanapura Dam - 10.64 km
13	Number of Irrigation projects	Major-76 Medium-135
14	Number of Ground water observation wells	1957
15	Number of Hydro-Observation Sites	72
16	Number of Flood Forecasting Sites	9
17	Water tourism sites	57

Source: *PDF of Krishna basin, India-WRIS.*

3.5 Topography

The western edge of the basin is an almost unbroken line formed by the Western Ghats whose height ranges from 600 m. to 2100 m. It has the heaviest rainfall and the most humid climate in the basin. Hardly 50 to 60 km. east of the Ghats lie the sparsely cultivated and undulating plains of the Deccan with a dry climate and poor rainfall.
The interior of the basin is a plateau, the greater part of which is at an elevation 300 to 600 m. Its general slope is eastwards. Great undulating plains, divided from each other by flat-topped ranges of hills are the main characteristics of this plateau. The hill-sides are marked by conspicuous, wide, terraces except in the southern part where the hills are frequently crowned with great 'tors' or rounded hummocks of bare rock, the result of constant weathering.

3.6 Climate

The Krishna basin has a tropical climate. The climate is dominated by the southwest monsoon, which provides most of the precipitation for the basin. High flow in the rivers occurs during the months of August-November and the lean flow season is from Aril to May. Climate types range from per-humid through dry sub-humid in the west through semi-arid in the central and eastern parts of the basin. The south-central part of the basin is truly arid.

3.7 Rainfall

Like most other parts of India, the Krishna basin receives its maximum rainfall during the south-west monsoon. The monsoon winds strike the west coast of the Indian peninsula from the west and south-west and strike the Western Ghats or the Sahyadri Range, which present an almost uninterrupted barrier ranging from 610 m to 2,134 m in height.

3.8 Temperature

The western area of the basin being closer to sea, is less continental and presents a comparatively low annual range of temperature.In winter while the maximum temperature in all parts varies between 30 oC and 35 oC, the minimum shows the significant variations.The places away from the coast show decreasing minima. Night temperatures are the main elements which make the winters more severe in central and western parts.In summers, while the western parts show a moderate heating, an effect of altitude and nearness to sea, the places deep inside the land and those remote from the maritime influences and at comparatively lower altitudes, show higher temperature.In contrast to diurnal heating in these parts the cooling in the night is slow.

3.9 Land use and land cover

The total Krishna River basin area is very much fertile, but as the population is increasing day by day land of agriculture became built up very rapidly. The details about land use land cover are mentioned below.

Table3. *Land use and land cover statistics (2005-06)*

Sl No.	Category	Area (Sq. km)	% of Total Area
1	Built Up Land	5931.50	2.29
2	Agricultural	196434.14	75.86
3	Forest	25986.84	10.04
4	Grassland	273.54	0.11
5	Wasteland	19781.85	7.64
6	Water bodies	10540.13	4.07

Source: *PDF of Krishna basin, India-WRIS.*

1.6 Soils

Soil is composed of minerals, mixed with some organic matter, which differ from its parent materials in terms of its texture, structure, consistency, color, chemical, biological and other characteristics. Information on the soil profile is also required for simulating the hydrological character of the basin. The important soil types found in the basin are black soils (regur), red soils, laterite and lateritic soils, alluvium, mixed soils (red and black, red and yellow, etc.) and saline and alkaline soils.

(PDF of Krishna basin, India-WRIS)

4. Tasks done with Methodology and date

A. Creation of map to represent decadal demographic change in sub basins of Krishna River

The aim of the project is to calculate sub basin wise population change. One of the data source is district population data. After a detail study it is in knowledge that 36 districts in total are into the watershed of Krishna River, more specifically 8 districts of Maharashtra, 9 districts of Andhra Pradesh and 18 districts of Karnataka. (20.2.2017 to 27.2.2017)

⬇

This table of Excel sheet is joined with district map by the joining option of Arc GIS 9.3 software. (1.3.2017)

⬇

To fulfill the aim the map of Krishna sub basin and the map of districts with population data are selected then overlaid in Arc GIS. By the intersect option of the same software the district boundaries are cut into sub basin boundary, after intersected small polygons are created. (4.3.2017)

⬇

Then the areas of these polygons which are automatically calculated in Arc GIS are exported to Microsoft Excel sheet. The area which is automatically calculated is transferred to Sq Km. area. In excel sheet the area are calculated as in percentage of the total district area. Polygons are part of districts; according to the percentage of the area the polygons have it is assumed the amount of population must follow the same ratio. According to the percentage of the area the population is also calculated. (6.3.2017)

⬇

Polygons of sub basin are clubbed and the summation of population is being calculated to get sub basin wise population. (7.3.2017)

⬇

The same method follows for the three census year 1991, 2001, and 2011.All these calculations are done in Microsoft Excel. (10.3.2017)

⬇

The calculated population data is connected to the Krishna sub basin map by table joining option in Arc GIS. It helps to create a graphical representation of the decadal population change, and finally the composite bar graph for each sub basins is made. (26.3.2017)

B. Creation of slope map

ASTER DEM (30 meter spatial resolution) is downloaded from USGS Earth Explorer. (28.3.2017 to)

⬇

Slope map is prepared from DEM in Arc GIS 9.3 software.(28.3.2017)

C. Land Use Land Cover map

NIH provides the land use land cover raster image of total Krishna basin. The main source is Indian Council of Agricultural Research, New Delhi. (30.3.2017)

⬇

Proper map of Land Use & Land Cover is prepared. (30.3.2017)

D. Creation of Falcon mark Water Stress Index

NIH provides sub basin wise water availability data.(3.3.2017)

⬇

Relating water availability data with population data of census year and make an index of water stress.(5.3.2017)

⬇

Prepared sub basin wise FWSI map.(10.3.2017)

3.1 Preparation of the datasets for creating map of decadal demographic change in sub basins of Krishna River

For this project two types of datasets are used, one is population data and another is Krishna river sub basin data. In India decadal census data are freely available. Downloading and preprocessing of the data became applicable to put into any analysis. The map and data of Krishna basin is provided by NIH (National Institute of Hydrology). For data processing Microsoft Excel and Arc GIS is used.

3.1.1 Census Data

Every country tries to quantify and keep a detail measurement of their demographic properties, because detail of past records is very much important for further plans. Plans for utilizing natural resources, plans for food production, plans for infrastructure and constructions, in a single term Plans for the nation. In India government is also concern about making Census reports. Here they make it in a decadal manner. After every ten years government employees do door to door surveys and take important information from a household. They mainly take the data in district level. The data includes urban population, rural population, income structure, number of villages, area, income, sex ration, community, cast, marriage age, household composition and size and so many other things. They also takes into account decadal variations, change in area. Data of union territories also recorded. (http://www.censusindia.gov.in)

For this present study only total population of a district is considered. First a detail study is done on the location, area, states and districts covered by the total Krishna river basin, then the structure of sub basins, its area and which districts are falling into which sub basin. According to this study district wise population is calculated and the data sheet is prepared in Microsoft Excel. For 1990 and 2000 it is very easy because there is only one column called population but for the year 2010 they add some minute details like they mentioned urban and rural population.

Table 4: *Decadal change in population of the districts of Maharashtra*

Districts	Total population of 1991	Total population of 2001	Total population of 2011
Osmanabad	1276327	1486586	1660311
Solapur	3231007	3849543	4315527
Kolhapur	2989507	3523162	3874015
Sangli	2209488	2583524	2820575
Satara	2451372	2808994	3003922
Pune	3006232	7232555	9426959
Ahmadnagar	3372935	4040642	4543083
Bid	1822072	2161250	2585962

Source: *(http://www.censusindia.gov.in)*

Table 5: *Decadal change in population of the districts of Andhra Pradesh*

Districts	Total population of 1991	Total population of 2001	Total population of 2011
Guntur	4106999	4465144	4889230
Hyderabad	3145939	3829753	4010238
Khammam	2215809	2578927	2798214
Kurnool	2973024	3529494	4046601
Mahbubnagar	3077050	3513934	4042191
Medak	2269800	2670097	3031877
Nalgonda	2852092	3247982	3483648
Rangareddy	2551966	3575064	5296396
Warangal	2818832	3246004	3522644

Source: *(http://www.censusindia.gov.in)*

Table 6: *Decadal change in population of the districts of Karnataka*

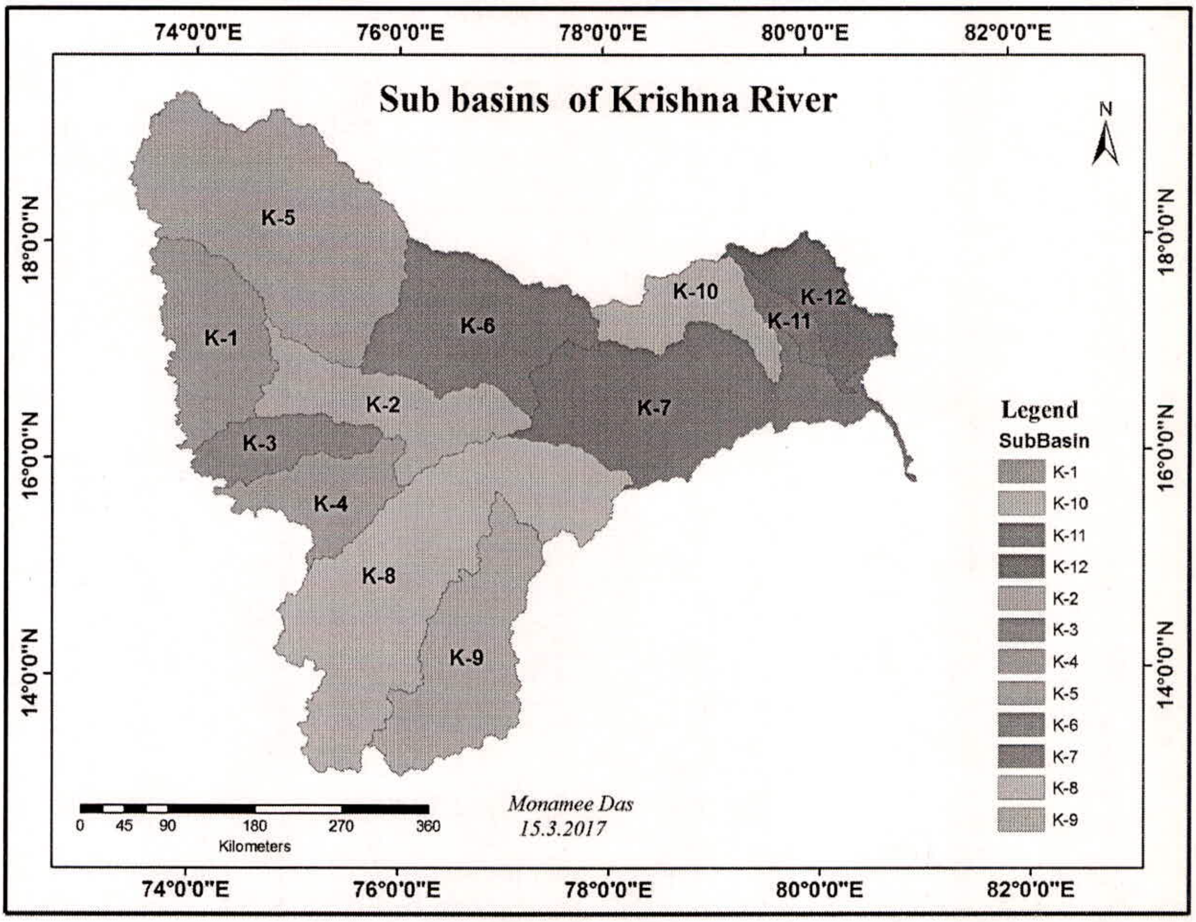
Districts	Total population of 1991	Total population of 2001	Total population of 2011
Belgaum	3583606	1651892	4778439
Bagalkot	1827650	1651892	1890826
Bijapur	1100340	2027140	2175102
Bidar	1255798	1502373	1700018
Raichur	140672	1806918	1924773
Koppal	269164	1140905	1391292
Gadak	1186367	971835	1065235
Dharwad	1089655	1790952	1846993
Uttar_Kannada	1220260	1353644	1436847
Haveri	1227128	971835	1598506
Bellary	1890092	3130922	2532383
Chitradurga	648882	1721669	1660378
Davanagere	507524	1439116	1946905
Shimoga	592187	1196089	1755512
Chikmagalur	1017283	1642545	1137753
Tumkur	2305819	2584711	2681449
Gulbagra	2582169	1353644	2564892
Hasan	1569684	1721669	1776221

Source: *(http://www.censusindia.gov.in)*

3.1.2 Krishna sub basin map

The present study is on Krishna River, more specifically its water accounting for sub basins of Krishna River. NIH provides the shape file for Krishna River and its sub basin. From the map the area of each sub basins are calculated. It is very important work o calculate the area because the population data is district wise and we have to calculate the sub basin wise population. That is why the area is being calculated.

***Figure 3**: Showing the Sub basins of Krishna River*



***Source:** Own Draft*

***Table no** 7. Showing the description of data sources and tools*

Sub basin No.	Name	Area(Sq Km.)
1	K-1	17910.6
2	K-2	17627
3	K-3	8660.0098
4	K-4	11503.2
5	K-5	45771.801
6	K-6	24533.6
7	K-7	34830.699
8	K-8	47710.398
9	K-9	23531.5
10	K-10	11300.4
11	K-11	3037.26
12	K-12	10443.7

Source: *Own Draft*

4. OUTPUTS

A. Creation of map to represent decadal demographic change in sub basins of Krishna River

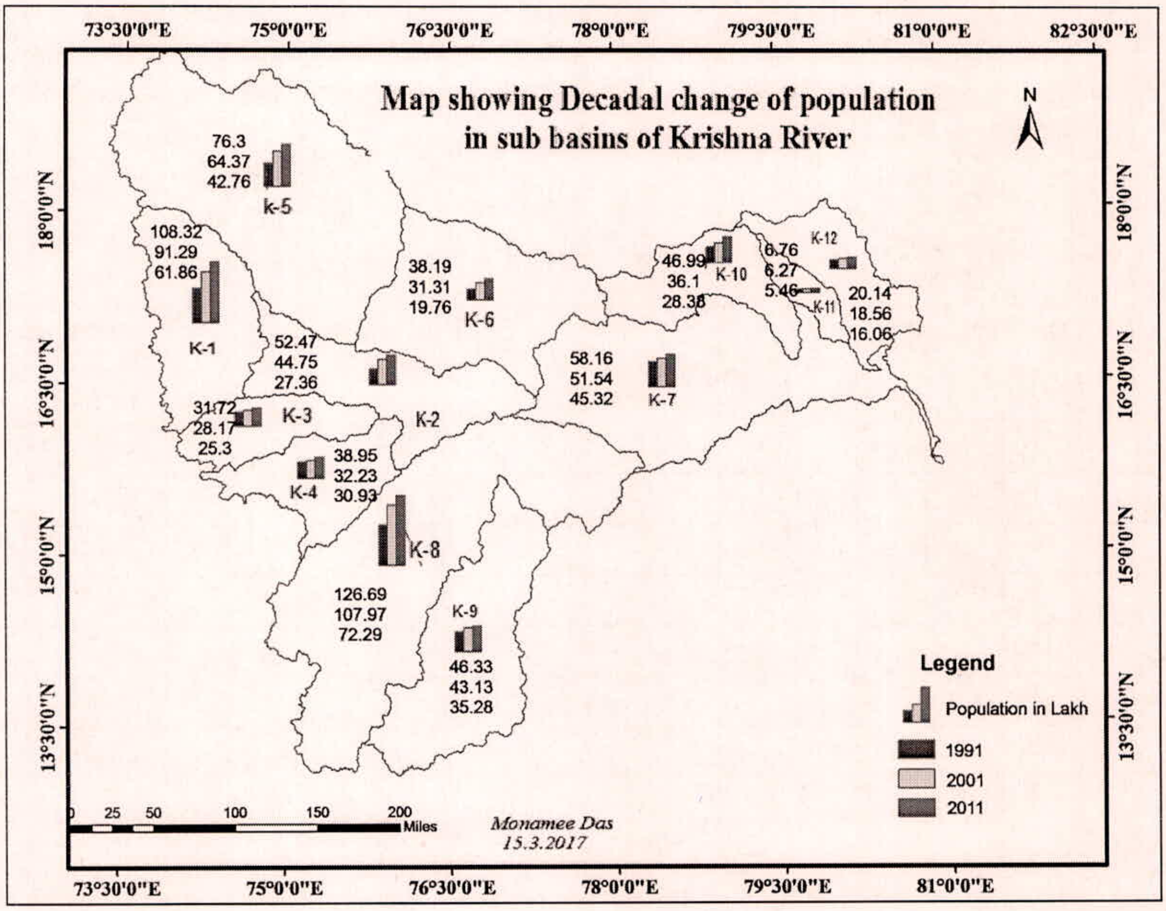
All the calculation and graphical representation shows that the population of each sub basin (K-1 to K-12) is increasing. Increase in the size of population is a very common fact of India everywhere. Though it has a rising trend still a fact is very noticeable that the rate of population increase in the time period of 1991 to 2001 is very high but it decreased later. The rate is slow in the time period of 2001 to 2011.

Table8. *Decadal demographic change in sub basins of Krishna*

Sub basin name	Population in 1991	Population in 1991	Population in 1991
K-1	61.86	91.29	108.32
K-2	27.36	44.75	52.47
K-3	25.3	28.17	31.72
K-4	30.93	32.23	38.95
K-5	42.76	64.37	76.3
K-6	19.76	31.31	38.19
K-7	45.32	51.54	58.16
K-8	72.29	107.97	126.69
K-9	35.28	43.13	46.33
K-10	28.38	36.1	46.99
K-11	5.46	6.27	6.76
K-12	16.06	18.56	20.14

Source: *Own Draft*

***Figure 4**: Map showing decadal change in population in sub basins of Krishna River*

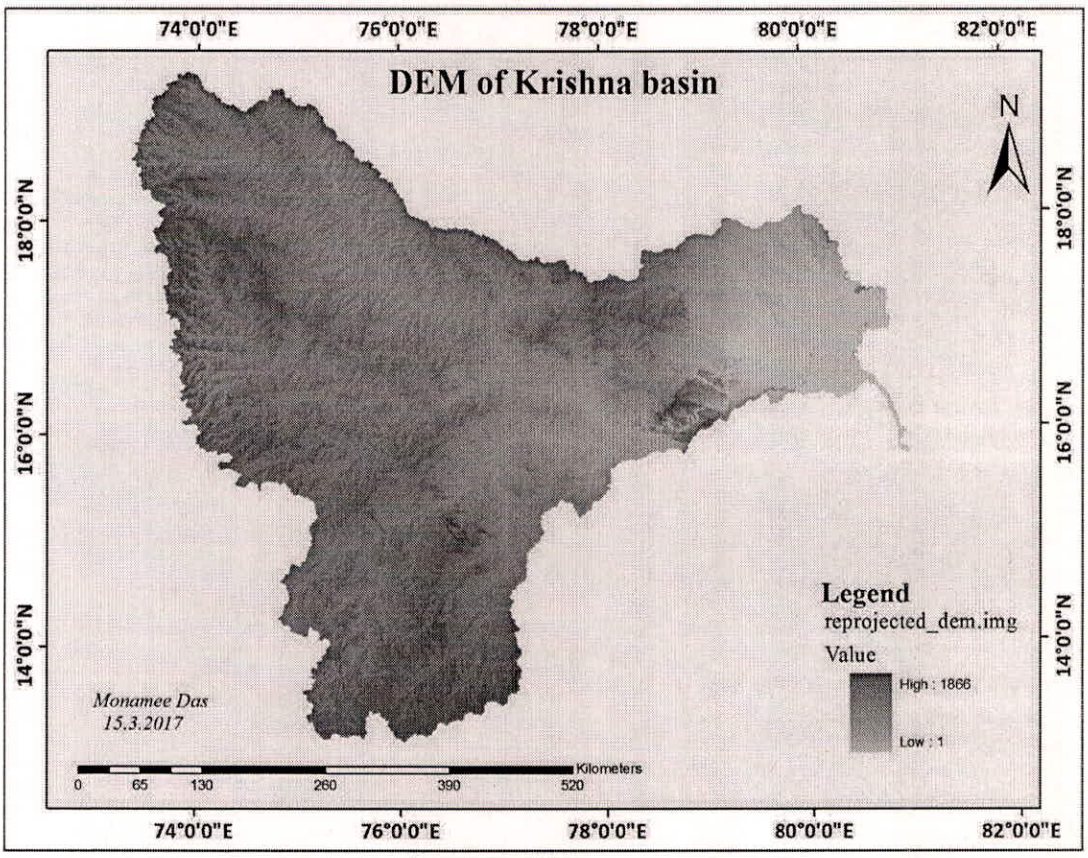


***Source:** Own Draft*

B. Creation of slope map

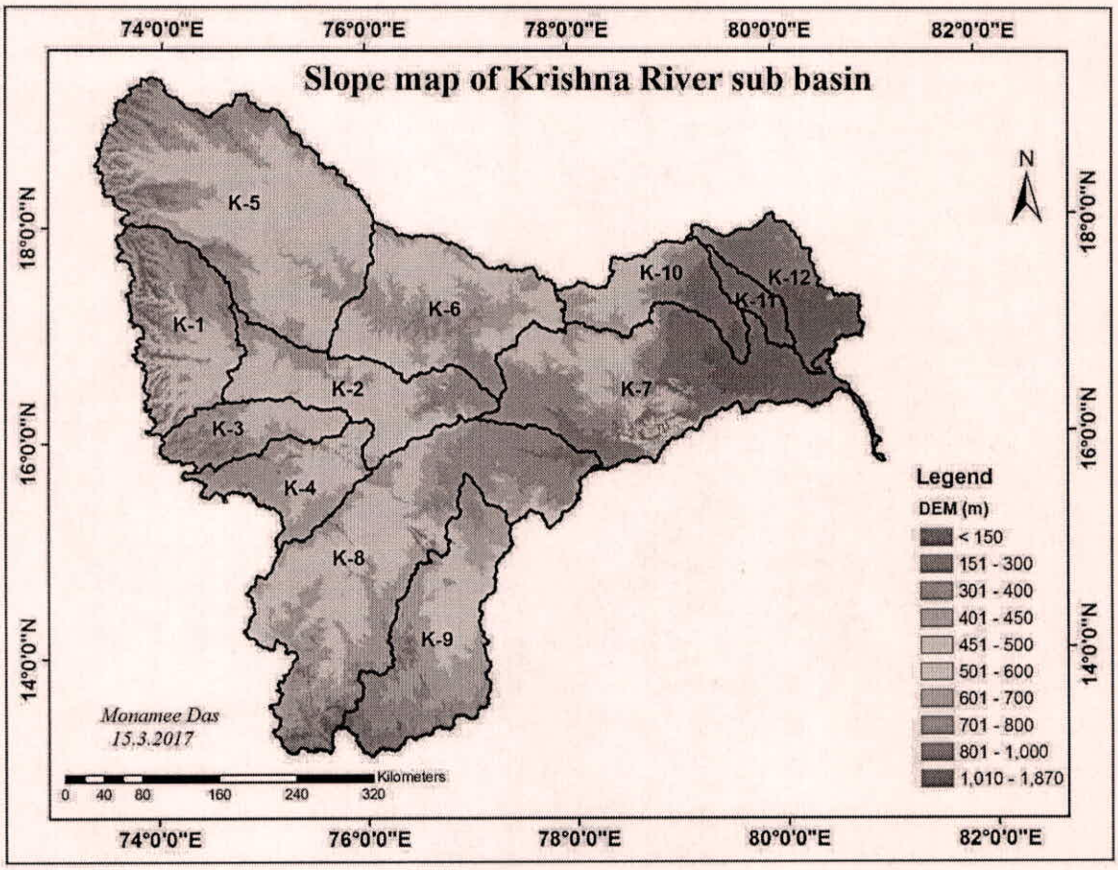
Slope is an important criterion of topography. For the purpose of making slope map Digital Elevation Model (DEM) is needed. From USGS Earth Explorer ASTER DEM of 30 meter resolution is downloaded. The DEM is then processed in Arc GIS software for making slope map. Maximum elevated area of the total Krishna River basin has the elevation of 1866 meter and minimum is 1 meter. To make a slope map the total renge of elevation is divided into 10 categories. The DEM and Slope map is represented in figure 5 and 6 respectively.

***Figure 5**: Digital Elevation Map of Krishna River*



***Source**: USGS Earth Explorer*

***Figure 5**: Digital Elevation Map of Krishna River*

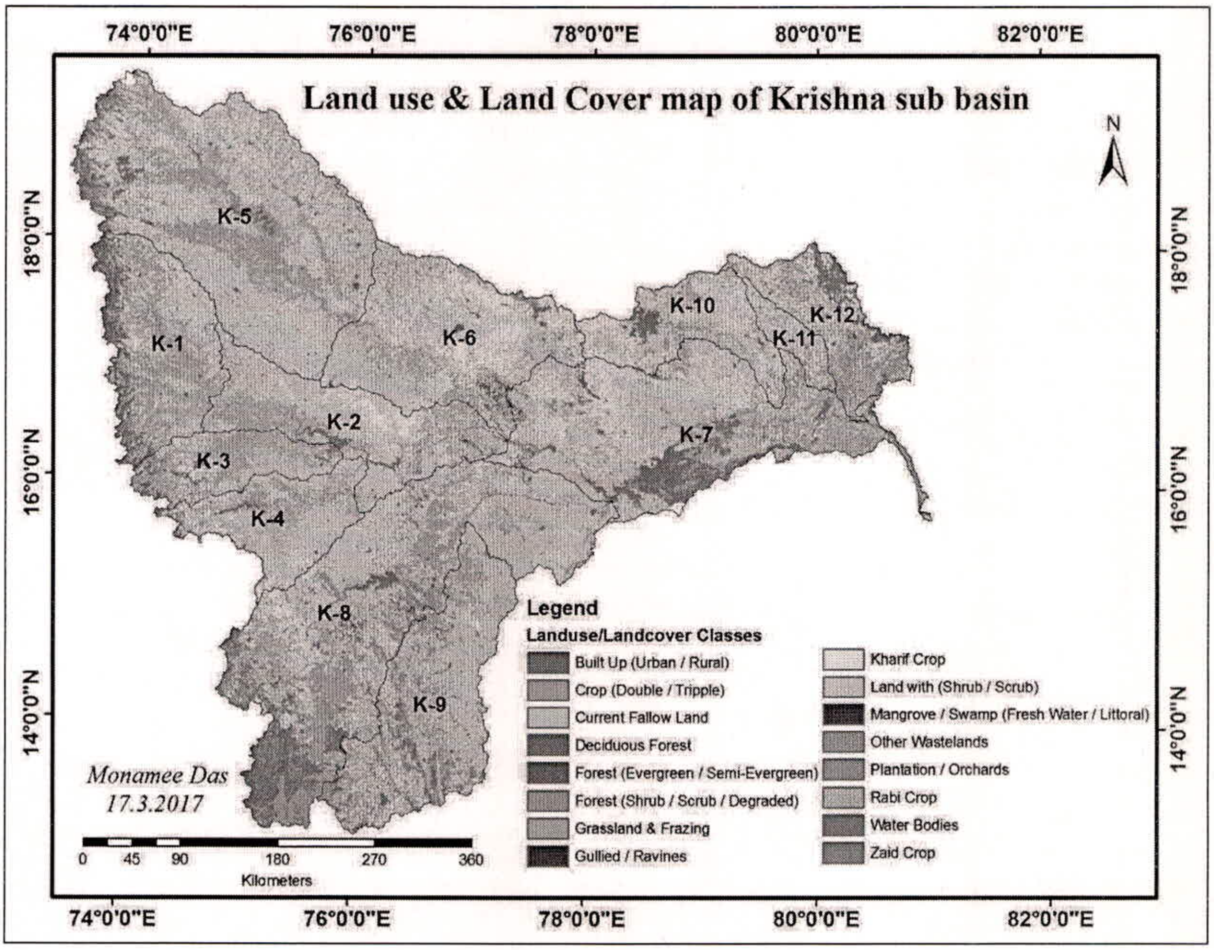


***Source**: own draft*

C. Land Use Land Cover map

Land Use Land Cover is one of the parameter which controlled the water flow of an area. For making a detail Land Use Land cover Map NIH provides a raster image of land use and land cover, and it is processed in Arc GIS in order to make a LULC map.

***Figure 5**: Land Use Land Cover map of Krishna River Basin*



***Source**: Indian Council of Agricultural Research, New Delhi*

D. Falcon mark Water Stress Index

When describing water availability in a country, the Falkenmark Water Stress Indicator, which was developed by the Swedish water expert Falkenmark in 1989, is one of the most commonly used indicators. Originally, the indicator based on the estimation that a flow unit of one million cubic metres of water can support 2,000 people in a society with a high level of development, using Israel as a reference by calculating the total annual renewable water resources per capita. Water availability of more than 1,700m³/capita/year is defined as the threshold above which water shortage occurs only irregularly or locally. Below this level, water scarcity arises in different levels of severity. Below 1,700m³/capita/year water stress appears regularly, below 1,000m³/capita/year water scarcity is a limitation to economic development and human health and well-being.

Despite its global acceptance, this indicator has numerous shortcomings. First of all, only the renewable surface and groundwater flows in a country are considered. Moreover, the water availability per person is calculated as an average with regard to both the temporal and the spatial scale and thereby neglects water shortages in dry seasons or in certain regions within a country. Furthermore, it does not take the water quality into account at all nor does it give information about a country's ability to use the resources. Even if a country has sufficient water according to the Falkenmark indicator, these water resources possibly cannot be used because of pollution or insufficient access to them. Values of water availability and water demand for selected countries are depicted in the figure below.

NIH provides me the data of water availability in MCM and it is converted to m^3 and then the formula is applied to achieve the index for the year of 2001 and 2011.

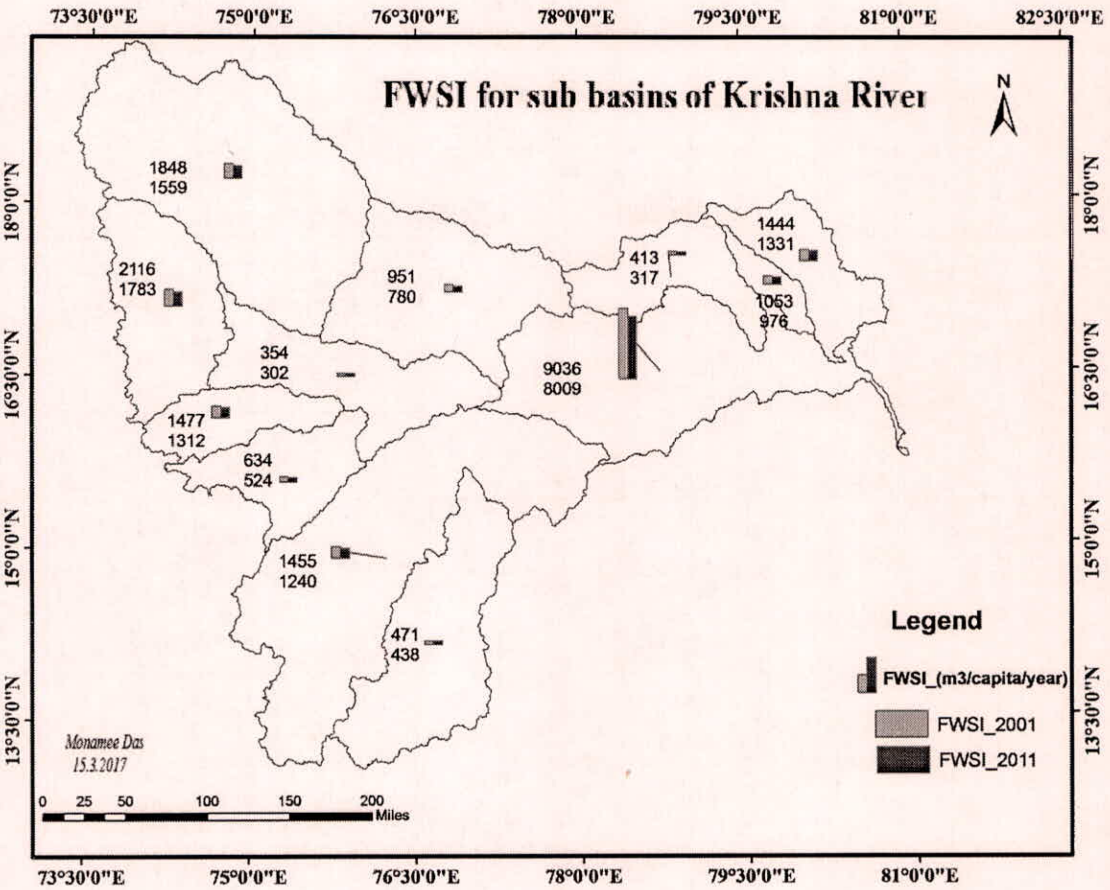
Analyzing the datasets give the result that due to the increasing rate of population water stress index in increased from the year of 2001 to 2011. In 2011 only K-1 is not in a water stress situation.

***Table 9**: FWSI of sub basins of Krishna River*

Sub Basins	WATER_ AVAILABILITY_ MCM	WATER_ AVAILABILITY_ m3	POP_2001	POP_2011	FWSI_2001 (m3/cap/yr)	FWSI_2011 (m3/cap/yr)
K-1	19318.87	19318874223.52	9128983	10832291	2116.21	1783.45
K-2	1583.80	1583802322.62	4475073	5246566	353.92	301.87
K-3	4160.65	4160653638.15	2816954	3171543	1477.00	1311.87
K-4	2042.11	2042111592.42	3222801	3895337	633.64	524.25
K-5	11894.81	11894811545.30	6437004	7630403	1847.88	1558.87
K-6	2977.10	2977098195.53	3131135	3818606	950.80	779.63
K-7	46575.72	46575715940.05	5154305	5815652	9036.27	8008.68
K-8	15708.13	15708130236.45	10796874	12669413	1454.88	1239.85
K-9	2030.04	2030037195.80	4312882	4633281	470.69	438.14
K-10	1490.40	1490401053.64	3609954	4699200	412.86	317.16
K-11	659.80	659804661.82	626739	676080	1052.76	975.93
K-12	2680.91	2680906249.14	1855973	2014069	1444.47	1331.09

***Source:** NIH*

***Figure 6**: WFSI for sub basins of Krishna River for the year of 2001 and 2011*



***Source:** Own Draft*

STREAM FLOW MODELING OF A PART OF SUBARNAREKHA RIVER BASIN USING SWAT MODEL

Internship report

Submitted by

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For the partial fulfillment of the

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1. INTRODUCTION

Existence of life depends on water resource. To develop an idea for the water resource development and management of the Govindpur watershed is the intension of this study. The integrated watershed management approach has been accepted everywhere as one of the best techniques for natural resource management but in few cases it has been applied because of the lack of required framework or lack of technical knowledge, but in this present days expertise are trying to do their best for improving sustainable use of any natural resources.

Subarnarekha River is situated in the north-east corner of the Peninsular India; the Subarnarekha basin has a long sausage shape. Subarnarekha literally means golden line. According to legends, in ancient times, gold was being extracted in the river's bed close to its origination point near Piska village, close to Ranchi. Subarnarekha basin extends over the states of Jharkhand, Orissa and comparatively smaller part in West Bengal having a total reported area of 29,196 Sq.km and geographically calculated area of 25,792.17 Sq.km with a maximum length and width of about 297 km and 119 km. The basin encompasses 12 districts overall (Census 2011) 7 of Jharkhand, 2 of Orissa and 3 of West Bengal.

Considering the outlet, Govindpur watershed is delineated. The watershed lies in the south west corner of the main Subarnarekha basin. The total area is 4,419 Sq.km. The total area is covered by Orissa state. Within the watershed 5 sub basins is calculated by the software.

1.1General

Water is one of the most valuable and precious resource of this world. For existence of every living being water is one of the most essential requirements. To maintain the ecological balance properly it plays also important role. To run the climatic factors properly it is also necessary to maintain water sources properly. It is one of the most important natural resources which have to be managed so properly to reduce most of the disputes over water in all over the world. Every country is trying to manage this resource properly and save it from pollution. In this recent fifty years India is also doing good management studies over water resource. For management of water resources it is important to go through the hydrological processes carefully, because a detail study is the only key for management purpose.

The National Water Policy of India (2002) recognizes that development and management of water resources need to be governed by national perspectives and aims to develop and conserve the water resources in an integrated and environmentally sound basis. It emphasizes development of our water resources by intensifying research efforts with use of space technology and developing an information system.

Central Water Commission (CWC), an attached office of Ministry of Water Resources, Govt. of India, and Indian Space Research Organization (ISRO), Department of Space, Govt. of India, joined hands for development of Web enabled Water Resources Information System of India (India-WRIS). Considering river basins as the basic hydrological units for water resources planning and management, the country is divided into 25 basins and 101 sub basins under India-WRIS project based on digital elevation model (SRTM DEM). For this study Govindpur watershed is delineated from Subarnarekha River and taken to run the Hydrological model SWAT. For this study the watershed is delineated by the ASTER DEM of 30m resolution.

2. AIM & OBJECTIVES

The main motive of this study is to apply the SWAT model in association with remote sensing and GIS techniques. It helps to evaluate the runoff for the watershed of Subarnarekha. The main focus of the study was to run simulation, calibration and validation of the SWAT model. The aim & main objectives of the present study are:

Aim

1. To modeling stream flow for the study area using Arc-SWAT.

Objectives

1. To perform Arc-SWAT for simulation.

2. To perform SWAT-CUP SUFI-2 software for calibration, validation of the discharge data of the study area.

3. To do Global Sensitivity analysis to check the sensitivity of parameters affecting discharge.

4. Water Balance calculation by using SWAT Check.

2.1 Software Used in the Study

The following software is used to set up the model and load the input database.

***Table no 1**. Showing the software's description*

SL.No.	Software Used	Description
1	ERDAS IMAGINE 2014	LULC Preparation Using Supervised Classification
2	Arc GIS 9.3	DEM Preparation, Co registration, Map Preparation
3	Arc SWAT 2009	Runoff Estimation
4	Arc SWAT CUP 2012	Calibration, Validation
5	Microsoft Office Excel 2007	Data Preparation

***Source**: Own Draft*

3. OVERVIEW OF THE BASIN & MODELS

3.1 Overview of the basin

3.1.1 Subarnarekha Basin

Subarnarekha River is situated in the north-east corner of the Peninsular India; the **Subarnarekha basin** has a long sausage shape. Subarnarekha literally means golden line. According to legends, in ancient times, gold was being extracted in the river's bed close to its origination point near Piska village, close to Ranchi. Subarnarekha basin extends over the states of Jharkhand, Orissa and comparatively smaller part in West Bengal having a total reported area of 29,196 Sq.km and geographically calculated area of 25,792.17 Sq.km with a maximum length and width of about 297 km and 119 km. The basin encompasses 12 districts overall (Census 2011) 7 of Jharkhand, 2 of Orissa and 3 of West Bengal.

3.1.2 Delineated Govindpur Watershed

Considering the outlet, Govindpur watershed is delineated. The watershed lies in the south west corner of the main Subarnarekha basin. The total area is 4,419 Sq.km. The total area is covered by Orissa state. Within the watershed 5 sub basins is calculated by the software.

3.2 Hydrological Model used

Hydrological model is a power full technique to management the natural resources. Models are essential tool which can be used to manage the hydrological process and validate the risks and benefits of Land use land cover and soil over various period of time (Spruill, C.A et al. 2000). The main objective of hydrological model is to extract most of the information for the management of water resources in a sustained manner to improve human welfare and conserve the Stream Flow Modeling a part of Subarnarekha Basin using SWAT Model. Create awareness for sustainable use of water, among the users with respect to planning, design and management of the project. A large number of hydrologic model are available for different aspect for water resource management. Geographic Information System (GIS) gives a convenient platform for water resource modeling. A huge number of models are interfaced with GIS. Remote Sensing and GIS techniques will provide useful information on the various problems related with water and land management, up to the date. Remote Sensing is a tool for dealing with spatial and temporal database, with high resolution. Hydrological model can be capable of producing all the specifications of water balance at a high temporal but low spatial resolution. The use of remote sensing data, with distributed hydrological model, provides a new way to obtain spatially distributed time series of input variables, parallel with calibration and validation for the hydrological model. The application of GIS has been widely used in water resource field. GIS stored data basically in the form of 'Geo-database', like satellite data, topographic data, thematic map and others. SWAT is one of the most widely accepted models introduced by United States Department of Agriculture (USDA). It's a physical based, continuous, long term simulation agricultural model. SWAT model helps to assessing the stream flow based of a river based on climate datasets.

3.2.1 SWAT Model

SWAT model run on a daily time steps. It is designed to predict the impact of land use land cover and management, sediment, and agricultural chemical yields upon stream flow. This model is process based, calculation wise efficient, and it is able to do continuous simulation over a long term datasets. The major components of this model are weather components, hydrological data, soil and temperature properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land management. In SWAT, firstly a watershed is being created by the use of a predefined outlet station. The next step is to divide river basin into multiple sub watersheds, which are then further subdivided into hydrologic response units

That consists of homogeneity in land use land cover pattern, management criteria, topographical characteristics, and soil specifications. The HRUs are represented as a percentage of the sub watershed area and may not be contiguous or spatially identified within a SWAT simulation. Alternatively, a watershed can be subdivided into only sub watersheds that are characterized by dominant land use, soil type, and management. SWAT was introduced by the U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS) primarily at the Grassland, Soil, and Water Research Laboratory in Temple, Texas (Gassman et al. 2007). The model was schemed for basin-scale applications. SWAT is able to predict water, sediment, and chemical yields in un-gauged basins (Gassman et al. 2007). Major components of the SWAT model include weather generation, hydrology, sediment, crop growth, nutrients, and pesticides (Neitsch et al. 2005). First version of the SWAT model was released in the early 1990s. The very latest version of the SWAT model is SWAT 2012. SWAT can be used in different division like hydrology, groundwater, agricultural management (SWAT theoretical documentation). Physical based input is use in SWAT model namely soil properties, elevation, weather variables. The hydrological cycle is simulated by SWAT model based on different weather datasets.

$$SW_t = SW_O + \sum_{i=1}^{t} (R - Q - E - W - G)$$

Where,

SWt = the final water content of
SWo = the initial soil water content
T = time in days
R = the amount of precipitation on day
Q = the amount of surface runoff
E = he amount of evapotranspiration on day
W = the amount of percolation and bypass exiting the soil profile bottom on day
G = the amount of ground flow on day

In the water balance equation the hydrological simulation process are shown, as precipitation, surface runoff, evapotranspiration and percolation and return flow. Precipitation and the other weather parameters, in general, provide the various inputs that control the water balance. The daily weather data required for SWAT are precipitation, temperature (maximum and minimum), solar radiation, wind speed, and relative humidity. These data can be observed or generated using a weather generator. The weather generator is used to either generate daily weather data or to fill missing values in the input data.

For each HRU, Runoff is simulated, then it combined to acquire the total amount of stream flow for the sub-basins, the sub basins are further combines with other sub-basins stream flow to calculate the total stream flow for the whole basin. According to (Neitsch et al 2011), the surface runoff can be delineates by using two methods, they are modified SCS curve number method or the Green and Ampt infiltration method. The SCS curve number, which was used in this study, is a function of the soil permeability, land use and the associated moisture condition. The curve number varies non-linearly based on antecedent moisture condition. The basic equation used in the SCS curve number method is given by:

$$Q = \frac{(R - I)^2}{R - I + S}$$

Where, Q denotes the accumulated surface runoff or rainfall amount (mm), R is the rain depth for the day, I is the initial abstraction, which includes surface storage, interception and infiltration prior to runoff (mm) and S is the retention parameter (mm).

3.2.2 SWAT-CUP Model

SWAT CALIBRATION UNCERTAINITY PROCEDURES (SWAT-CUP) is a software program for calibration, validation of SWAT model. It was invented by Eawag, Swiss Fedral Institute that looks into the prediction of uncertainty of SWAT model. The parameters of the model can be chosen in accordance with the objectives of the study. The results obtained after using different variables and combination of variables among water content. Pressure head and cumulative outflow on the estimation of hydraulic parameters by inverse modeling were investigated in previous study (Abbaspour et al. 1999). GLUE is included in SWAT-CUP which is defined to partly show the possible similarity, PARASOL, and SUFI-2 are the methods to give combined objective functions into a criteria which is globally optimized which uses SCE-UA algorithm.

A soil map is considered in model parameterization, in SWAT-CUP of a watershed model which can be similar soils in different parameters due to difference in climate, land use and soil management. Different calibration programs allow parameters combinations of soil, land use, hydrological group and sub-basin specification which are linked to SWAT (Abbaspour et al. 1999).

X_<parname>.<ext>_<hydrogrp>_<soltext>_<landuse>_<subbsn>

Where,

x = indicate the type of change to be applied to the parameter

<Parname> = SWAT parameter name

<ext> = SWAT file extension

<hydrogrp> = Soil hydrological group (A, B, C, D)

<Soltext> = Soil texture

<Landuse> = Land use category

<Subbsn> = sub-basin number

1.3.3 SUFI-2 (Sequential Uncertainty Fitting)

SUFI-2 can be used for calibration of model and uncertainty analysis, it is a multisite and semi-automated global search procedure. In SUFI-2 we take an account of the homogeneity in distribution to demonstrate the uncertainty of input variables. In this model the output uncertainty is quantified by 95% prediction uncertainty, which is calculated at 2.5% and 97.5% levels of cumulative distribution of output variables obtained from the method Latin hypercube sampling. The parameter uncertainty is directly proportional to uncertainty of output. In SUFI-2 p-factor is used for the assessment of uncertainty, r-factor is also a significant method that can be used, which is the average thickness of the 95PPU band divided by the standard deviation of the measured data. The value of p ranges between 0-100 percent, while the r-factor ranges between 0 to infinity. The exact correspondence to measurement the data is p-factor of 1 and r-factor of 0. The parameter uncertainties are the desired parameter ranges after obtaining satisfactory values of r- factor and p-factor. The most reliable result can be measured by the R2 or Nash-Sutcliff coefficient method amongst the observations and the final "best" simulation.

4. STUDY AREA

4.1 Location

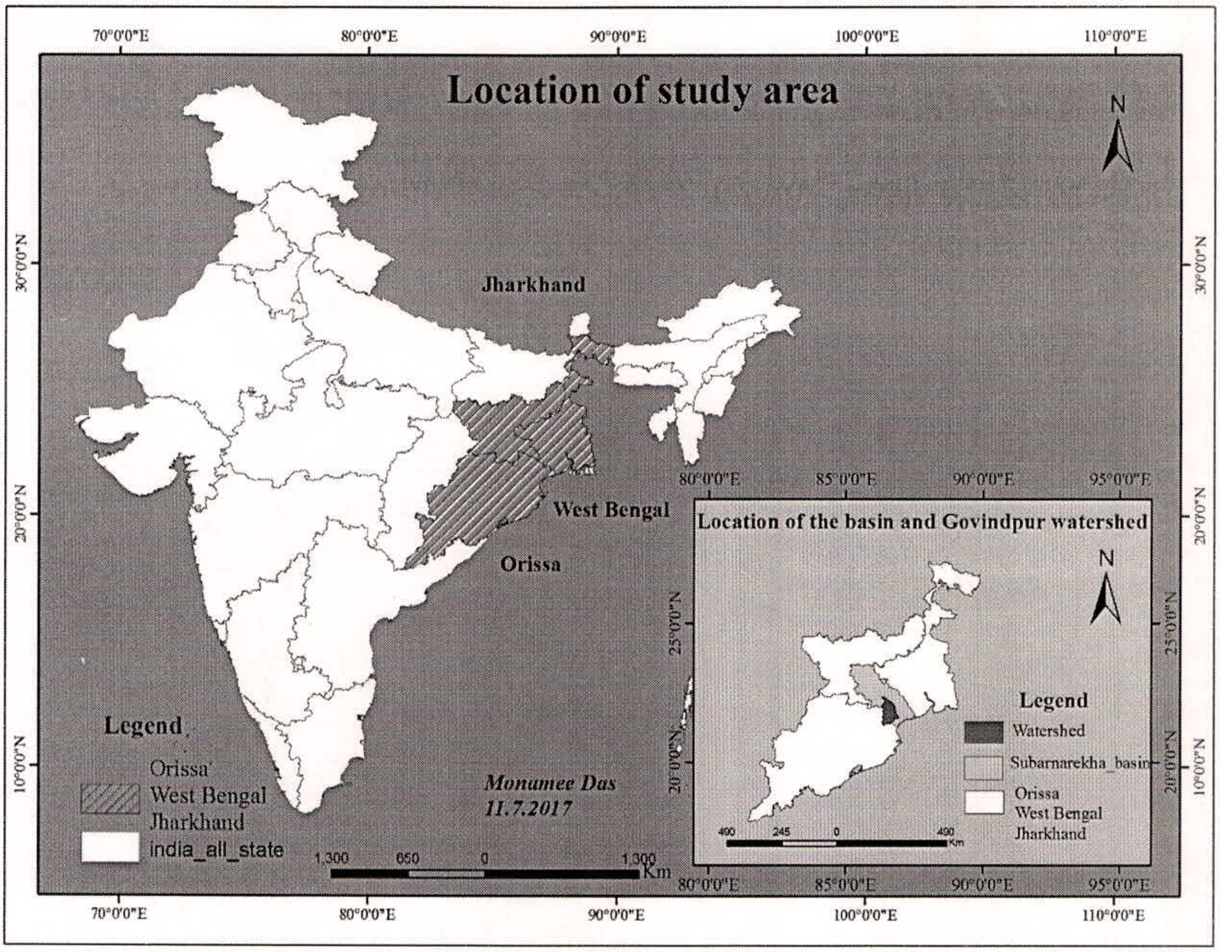
This study is done over an intermodal part of Subarnarekha River, more prominently a watershed delineated by the Govindpur (discharge station) outlet. The study area (Fig no.1 & 2) situated in the latitude range of 21° 31′N to 22° 35′N and longitude 86° 27′E to 86° 97′ E with an elevation of 4 m to 1189 m above mean sea level covering an area about 4419 sq. km in the state of Orissa, India.
Runoff simulation of the intermodal part of Subarnarekha River was calculated, which flows over North east corner of peninsular India.

4.2 Subarnarekha river system and Govindpur watershed

Situated in the north-east corner of the Peninsular India, the **Subarnarekha basin** has a long sausage shape. Subarnarekha literally means golden line. According to legends, in ancient times, gold was being extracted in the river's bed close to its origination point near Piska village, close to Ranchi. Subarnarekha basin extends over the states of Jharkhand, Orissa and comparatively smaller part in West Bengal having a total reported area of 29,196 Sq.km and geographically calculated area of 25,792.17 Sq.km with a maximum length and width of about 297 km and 119 km. The basin encompasses 12 districts overall (Census 2011) 7 of Jharkhand, 2 of Orissa and 3 of West Bengal. The basin spreads over 15 parliamentary constituencies (2009) comprising 7 of Jharkhand and 4 each of Orissa and West Bengal. Out of these only 9 parliamentary constituencies are broadly covered under the basin. The rest 6 parliamentary constituencies have negligible area of less than 3% falling under the basin.

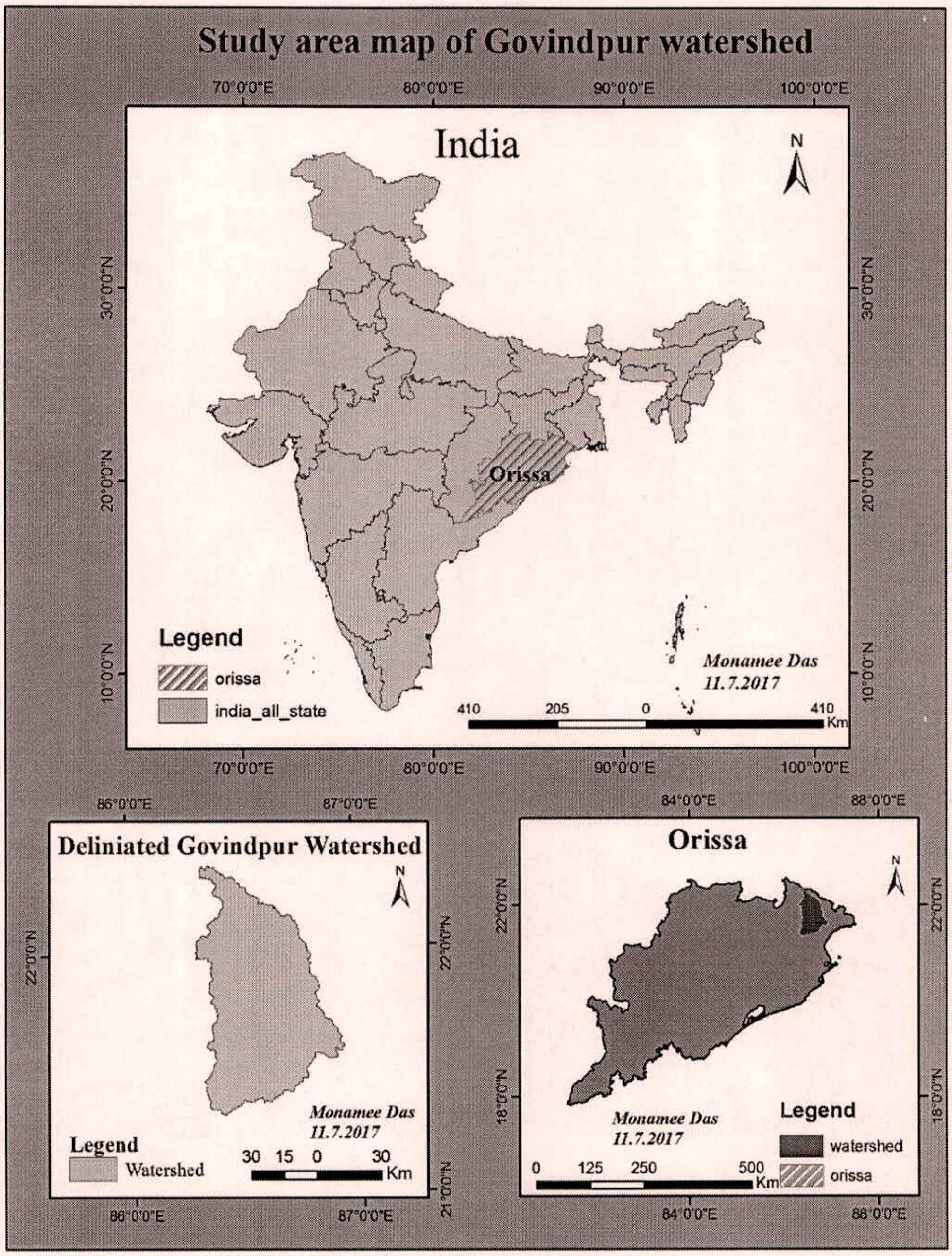
Considering the outlet, Govindpur watershed is delineated. The watershed lies in the south west corner of the main Subarnarekha basin. The total area is 4,419 Sq.km. The total area is covered by Orissa state. Within the watershed 5 sub basins is calculated by the software.

***Figure 1**: Showing the location of the study area*



***Source**: Own Draft*

***Figure 2**: Study area map of Govindpur watershed*



***Source**: Own Draft*

4.3 Physiological and topographical features

The total Subarnarekha basin is bounded by the Chota Nagpur plateau on the north and the west, by the ridges separating it from Baitarani basin on the south, by the Bay of Bengal on the south-east and by the Kasai Valley of Kangsabati River on the east. The delineated watershed is only covering Orissa district.

Part of the Mayurbhanj district of Orissa lying in the watershed, is hilly and well-forested. The coastal plains cover parts of Balasore district in Orissa.

The general slope of the watershed is from north-west to south-east. The area covered under different elevation zones of the watershed is. The highest peak with an elevation of 1189 m is located in Garhjat range near Udala tehsil, Mayurbhanj district in Odisha. More than 35% of the area of the watershed lies in the hilly region and dense forested area. Major area of the plain region of the Subarnarekha basin falls under the 100-300 m elevation zone.
The geological formations occurring in the basin are (i) Pre-Cambrian or Archean (ii) Tertiary and (iii) Alluvium plains. Out of these, Pre-Cambrian formations mostly cover Jharkhand and West Bengal regions and Tertiary and Alluvium plains cover the basin area in Orissa. The Archean formations mostly comprise Geneiss, Micagenists, Phyllites, Dolomites and Granites. The underlying rock is highly undulating. This region contains some of the richest coal and ore deposits like iron and bauxite.

4.4 Precipitation

In this watershed Rainfall varies greatly, both annually and seasonally. The average annual rainfall for the years 1972-2005 is 1444.53 mm according to the 0.5° grid data and 1385.75 mm for the years 1971-2004 according to the 1° grid data.
The rainfall in the basin gradually increases on moving from the upper part of the basin to the lower part of the watershed.

4.5 Temperature

April and May are the hottest months of the year throughout the basin with the temperature rising to about 37°C. The minimum temperature is observed in the months of December and January with temperature dipping to around 12°C. The average annual maximum temperature recorded for 1969-2004 is 31.46°C for the basin. In the month of January, the mean average temperature over the basin is around 18°C. In April, the mean temperature is about 30°C, whereas in the month of July it is about 28°C.

4.6 Soil Quality

The general data regarding the soils of the basin indicate that near about 80% of the basin comprises of soils with fine and medium texture. Rocky and other types of soils constitute around 12% of the basin. Severe soil erosion takes place in 23.74% of the basin area and approximately 1.4% of the basin area poses very severe soil erosion. Out of the basin area for which data is available, around 20% which is under deltaic area is highly productive and 17.21% of area is moderately productive. The areas near Mayurbhanj district comprises of low productive soil. In the particular watershed delineated by Govindpur discharge station, the main types of soils are Loamy-skeletal, Coarse-loamy, Fine-loamy, Fine (according to their particle size).

4.7 Land Use Land Cover

The land use pattern is an outcome of the interaction and interplay of the various physical conditions of the area. It gives not only the land coverage but also an insight into the nature of environmental degradation in the catchment area of the basins. Remote sensing technique has been extensively used to map this ever changing phenomenon.

5. Methodology

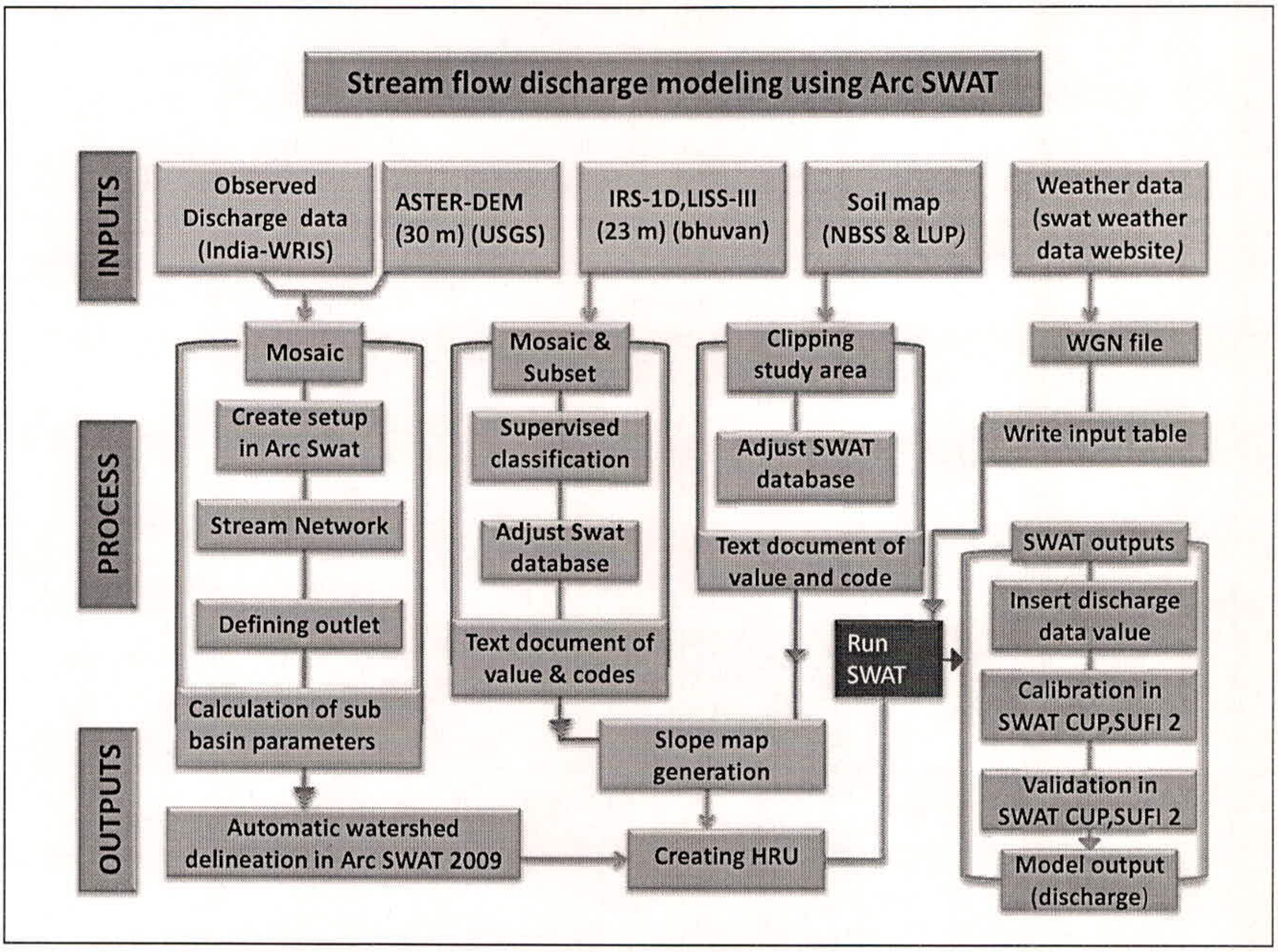


Figure 3.*Methodology flow chart*

5.1 Preparation of the Database for the Study Area

This study area falls in the state of Orissa state, for carrying out the study various types of multispectral, multi temporal and dynamic data was collected. India-WRIS provides discharge data of a stream. Here the discharge data of Govindpur station is used for watershed delineation. The satellite imageries of IRS-1D LISS-III, ASTER DEM (30m) are obtained from the bhuvan web portal and (USGS) which is freely available. Meteorological data such temperature, solar radiation, relative humidity, precipitation, wind speed is taken from http://globalweather.tamu.edu/. Land Use Land Cover map has been prepared using supervised classification technique from the help of the satellite imagery. ERDAS imagine 2014 software has been used for this classification purpose. The soil map was prepared by using digitization from toposheet of NBSS & LUP, Nagpur. For this study NIH provides the soil map.

Table 2.*Sources with Description of the input data for this study*

Data Type	Source	Type of data	Description
Topography (Elevation data)	USGS Earth Explorer	30 m Spatial resolution	ASTER Digital Elevation Model
Land use/Land cover	IRS-1D,LISS-III satellite imagery (Bhuvan)	30 m Spatial resolution	Land use Land cover Classification
Soils	NBSS & LUP, Nagpur (Hardcopy of soil map was converted into digital form)	-	Soil Classification
Weather Data	http:/globalweater. tamu.edu/	Daily	Minimum &Maximum Temperature, precipitation, Solar Radiation, Relative Humidity, Wind Speed
Stream Flow Data	India-WRIS	Daily	Daily Stream Flows measured at gauging stations

Source: *Own Draft*

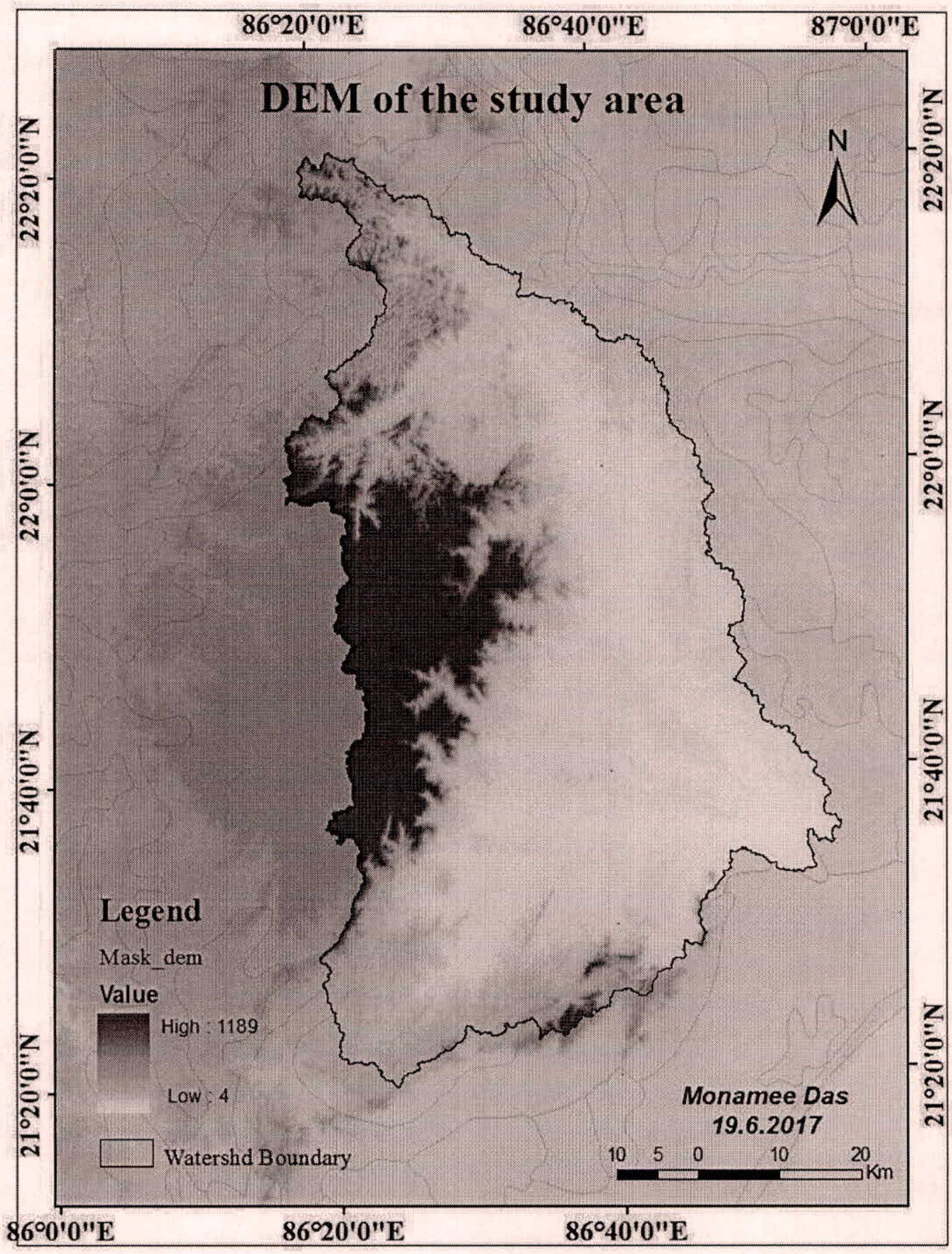
5.1.1 SWAT-Model Inputs

To perform the model, primary steps are identification and delineation of the watershed and hydrological response units (HRUs). From ASTER DEM drainage network is delineated, where analytical technique of the Arc SWAT-2009 GIS interface was used. To calculate an acceptable numbers of HRUs within each sub basins, a perfect combination of land use, soil and slope (15%, 22%, and 15%) were used. To run this process the study area is divided into 5 sub basins and 40 HRUs. These combinations establish an acceptable drainage network description as regard to the management of dominant land uses, soil types within every sub basins, and an acceptable numbers of HRUs in each sub basins.

5.1.2 ASTER Digital Elevation Model (DEM)

A DEM is an array of numbers that represent the spatial distribution of elevation above some datum, it represents a topographic surface. For the current study ASTER DEM was used. The resolution of digital elevation models ranges from 15 to 90 m. For this study ASTER DEM was downloaded from the USGS Earth Explorer, it has 30 m spatial resolution. The basin area has been covered in a single tile. The study area which is delineated by Govindpur station is extracted from the downloaded DEM. The ASTER DEM of the study area is showing in the Fig no.3

Figure 3*: ASTER DEM of the study area*



Source*: USGDS Earth Explorer (*https://earthexplorer.usgs.gov/*)*

5.1.3 Soil Map

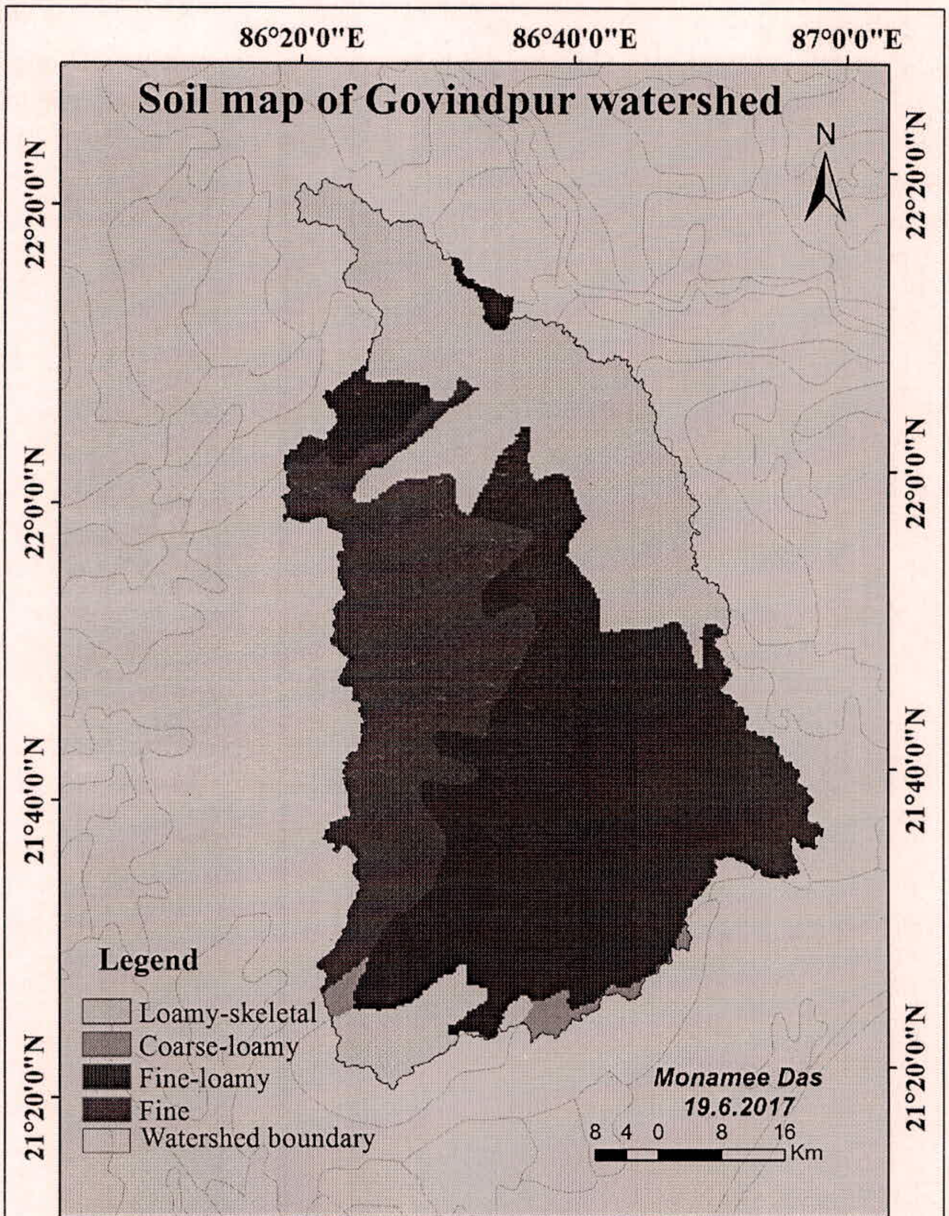
For SWAT Model one of the main major input is the physical properties of the soil. It plays a great role for any hydrological modeling. The basic requirement of the model is soil properties like texture, hydraulic conductivity, water availability etc. For this current study soil map has been digitized from two sources, one is NBSS (National Bureau for Soil Survey & Land Use Planning) and another is LUP, Nagpur, based on a predefined scale of 1:50,000 provided by NIH (National Institute of Hydrology). According to the soil properties the study area has been classified in to four categories namely Loamy-Skeletal, Coarse- Loamy, Fine-Loamy and Fine.Soil catagories are clearly shown in the figure no 3.

***Table no 3**. Showing soil categories and their characteristics*

Type	**Classes according to texture**	**Reclassified Classes According to SWAT database**	**Area (%)**
Soil	Loamy-Skeletal	FL-MD-C	27.26
	Coarse- Loamy	LS-D	22.90
	Fine-Loamy	CL-LS-C	1.64
	Fine	FL-LS-MD-D	48.12

***Source**: Own Draft*

***Figure 4**: Soil map of the study area*



***Source**: NBSS & LUP (Provided by NIH)*

5.1.4 LULC Land Use & Land Cover map

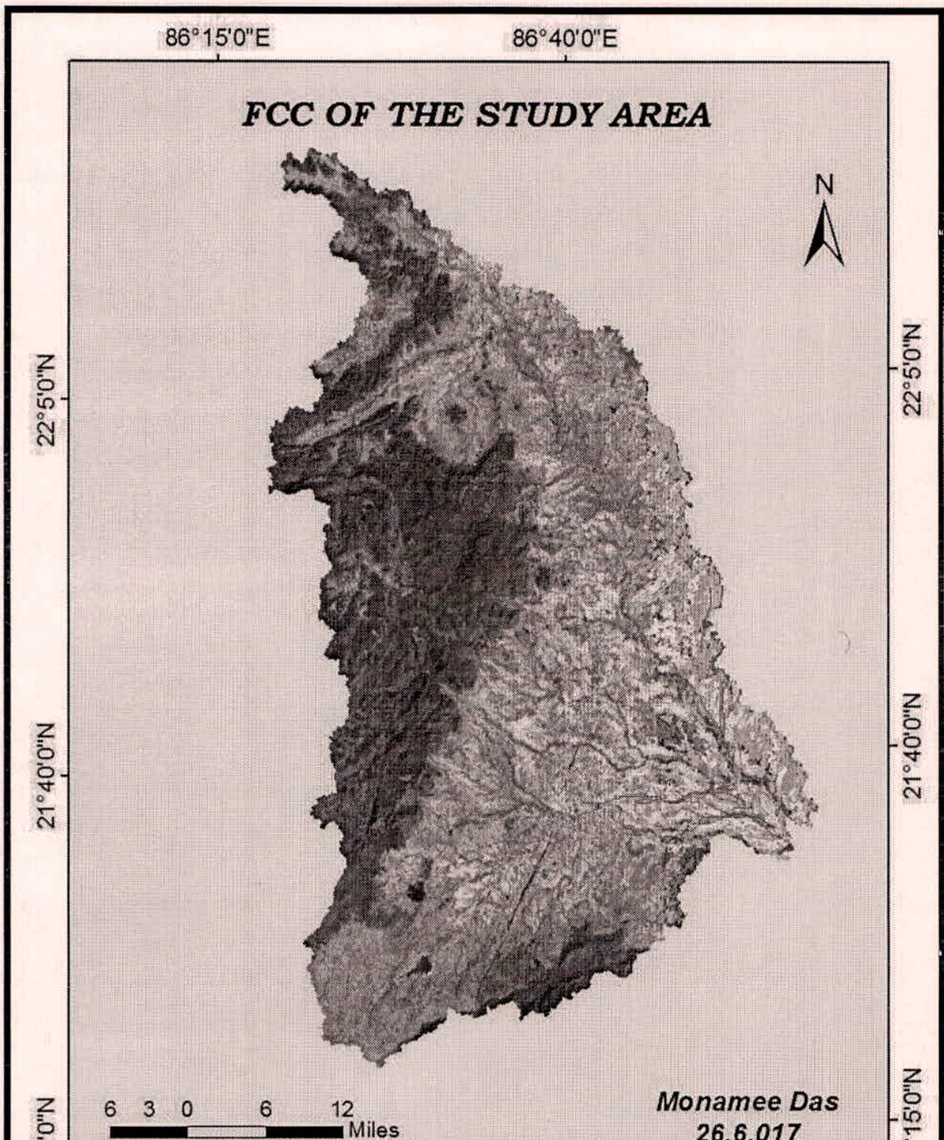
It is necessary to prepare a proper LULC (land use land cover) map to perform the model as it is one of the most essential factor effecting the runoff, infiltration, percolation, evapo-transpiration, drainage network, soil erosion in a basin. In this study a LULC map (Fig no.6) has been prepared by using remotely sensed satellite data. For this current study, LANDSAT-8 data has been used, after downloading the data from USGS Earth Explorer. The particular study area has been masked according to basin area using Arc GIS 9.3 software. There are eleven spectral bands in this sensor. Using this False Color Composition (FCC) has made (Fig no.5). There are several classification techniques which are dominantly used in the field of remote sensing. For this particular study supervised classification has done using software called ERDAS IMAGINE 9.2. According to spectral reflectance four land use land cover classes are made, those are deciduous, forest evergreen, water and barren land. Descriptions of the LULC classes are given in Table no.4

***Table no 4**. Specifications of different land use and land cover*

Type	Classes	Reclassified According to SWAT database	Area (%)
Land Use/Land Cover	Forest deciduous	FRST	14.14
	Shrub land	RNGE	26.89
	Agricultural land	AGRL	42.05
	Urban land	URBN	11.61
	Water body	WATR	5.49

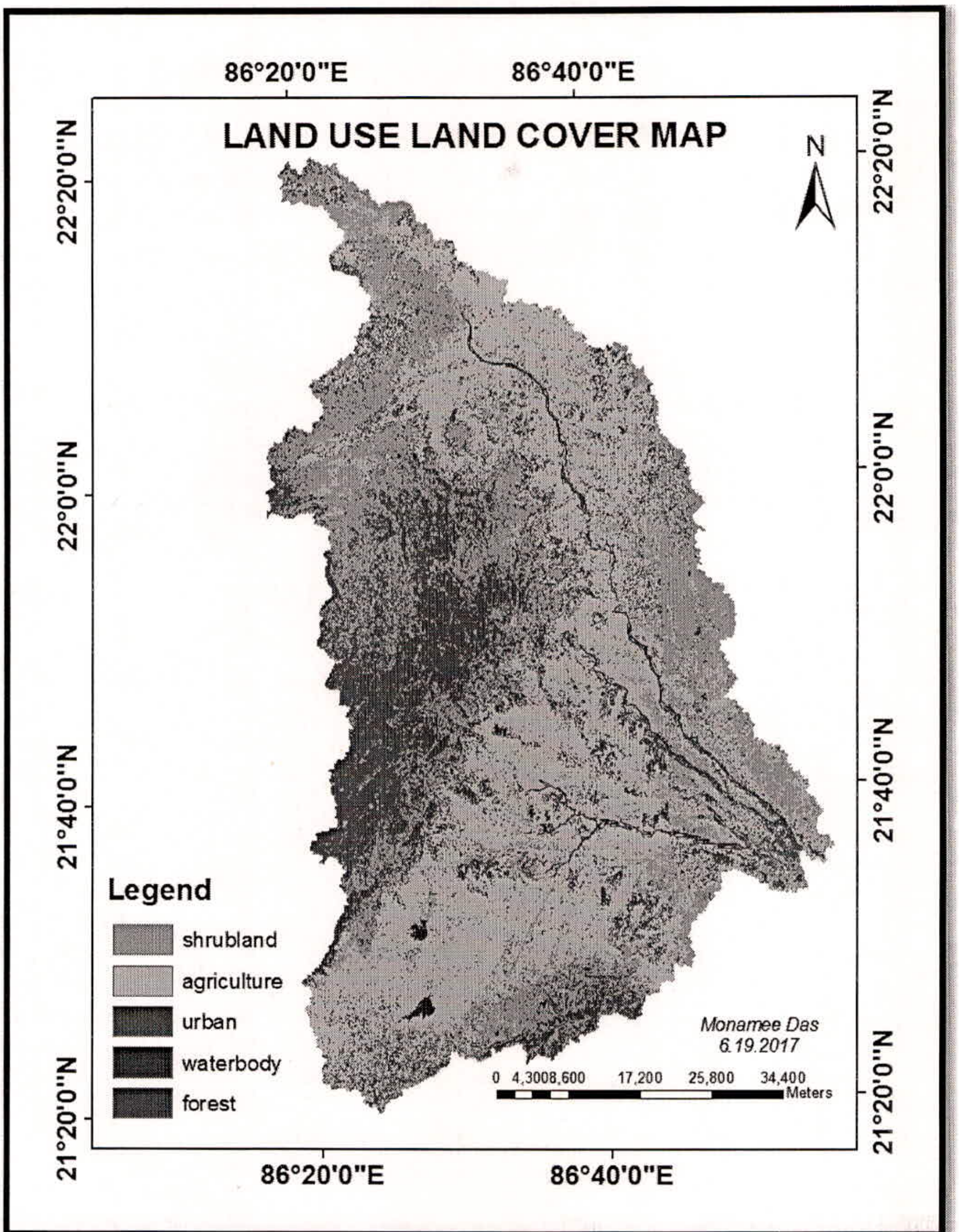
***Source**: Own Draft*

***Figure 5**: False colour composition of Govindpur watershed area*



***Source**: BHUVAN portal (*http://bhuvan.nrsc.gov.in/)

***Figure 6**:Land use land cover map of Govindpur Watershed area*



***Source**: Own Draft*

5.1.5 Slope Map

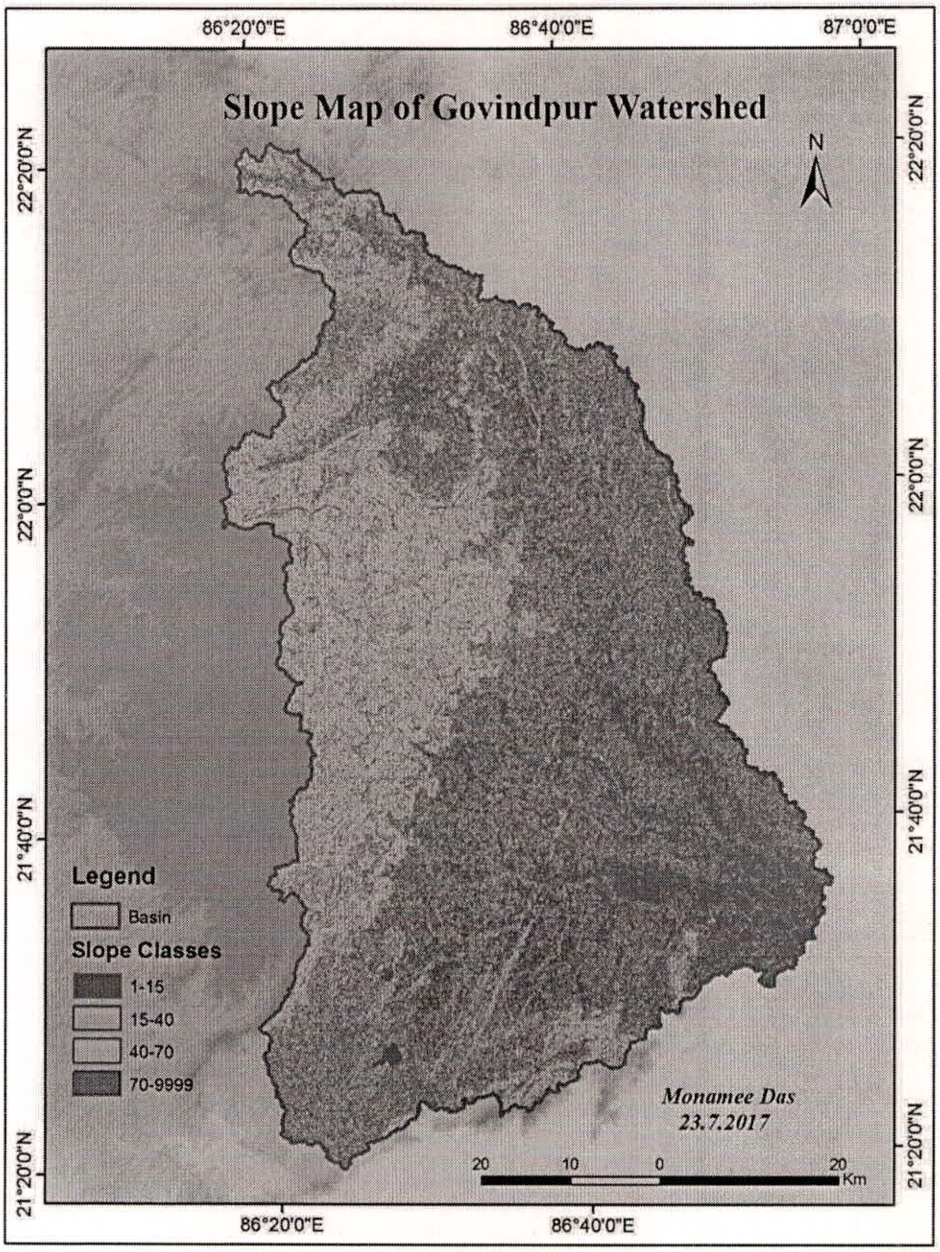
In Arc SWAT it automatically deliniate slope map taking consideration of DEM (ASTER DEM,30 meter)land use land cover parameters and soil properties. It is only nedeed to provide slope classes accordinng to ones perpose. Broadly there are two catagories-1.Single Slope, 2. Multiple slope. For this study multiple slope function is used and it is divided into four catagories, but maximum five classes can be taken. SWAT consider slope classes defined in percentage or area basis. In this study four classes are taken and classified as 1 to 15%, 15 to 40%, 40 to 70%, 70 to 9999%. In SWAT 9999 is taken as 100%. T he slope classes are clearly defined in the table no.5 bellow.

***Table no 5**. Specifications of different slope classes*

Slope Class	Lower Limit (in %)	Upper Limit (in %)
1	1	15
2	15	40
3	40	70
4	70	9999

***Source**: Own Draft*

***Figure** 7:Showing slope classes of Govindpur Watershed area*



***Source**: Own Draft*

5.1.6 Weather Data

For the calculation of the stream flows using Arc SWAT software, it is necessary to prepare a required weather database. Some statistics were generated using WGN EXCEL MACRO Software. All the weather data is collected from this website-(http://swat.tamu.edu/software/links-to-related-software/). It provides data of whole world, so one can easily select the data of their required station. For this study data of three weather stations are taken. One should keep it into mind that Discharge data station and weather stations are different. They provide the data of five weather parameters, e.g. Precipitation, temperature minimum maximum, wind speed, solar radiation, and relative humidity. All the dataset they provide it is in the form of daily time step. So it calculates discharge more preciously.

5.2 Arc SWAT 2009 Model Setup Simulation of Hydrological Process

The model has setup to establish hydrological simulation for a part of Subarnarekha river basin. The following steps has been followed to set up the model –

- SWAT project setup
- Automatic water shade delineation
- Land use and soil characterization (HRUs analysis)
- Write input tables
- Editing input information
- SWAT simulation

5.2.1 SWAT Project Setup

The first step of the model is to define the location of the project, and its Geo database. All associated files are stored in the specified database.

5.2.2 Data Processing

To estimate the stream flow, the required database has generated, to fulfill all the objectives for the current study, required database have successfully developed. The detail steps have explained in the flow chat of the methodology.

5.2.3 Automatic Watershed Delineation

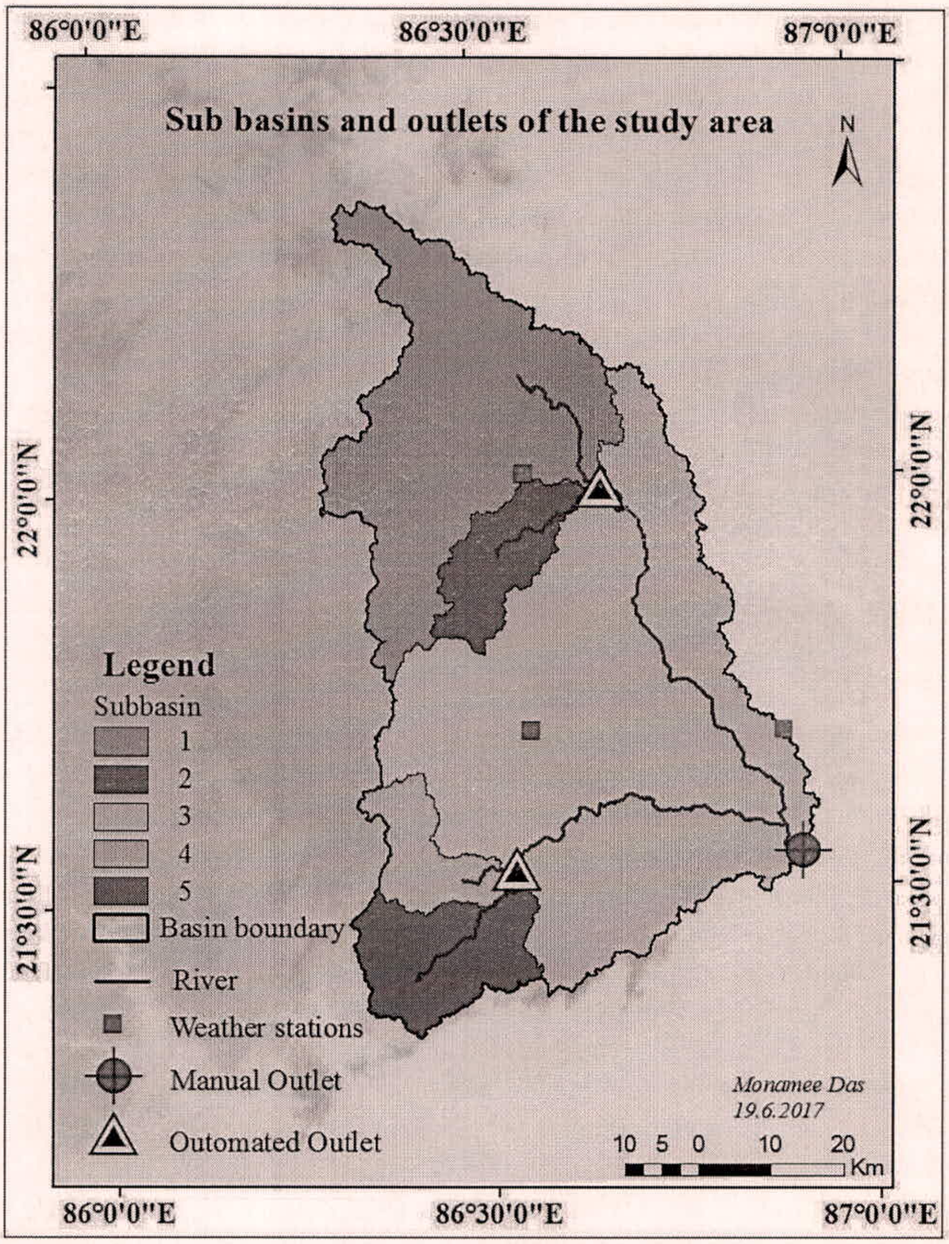
Arc SWAT 2009 automatically delineates watershed (Fig no.8) into sub-watersheds based on DEM and the river's drainage network. The ASTER DEM which is clipped for the area has imported in the model, a masking of polygon has created manually in Arc SWAT (grid format) which has inserted in the model to extract the area of interest. The DEM has to be pre-processed for the determination of the size and number of sub watersheds based on the threshold area. It formed 5 sub basins (Fig.7). Once the watershed and sub-watersheds boundaries are delineated, a specific outlet of the study area has defined at Govindpur (13m elevation) point to generate the whole watershed. As the study area is not a whole basin it's just a part of it so the concept of inlet became necessary to bring here.

At last all the geometric parameters of every sub basins and stream reaches are calculated and saved as a vector file (.shp format). The area delineated by the software has been found to be 4419 sq. km.

5.2.4 HRU Definition

The Hydrological Response Unit (HRUs) is basically which divided the whole watershed into different homogeneous unit with respect to land use land cover, soil types and slope criteria at each grid. HRUs are a part of sub basin which produces a unique land use/management/soil attributes. Land use, management and soil may be scattered throughout the study area but for HRUs creation it should be put together in one group. As a thumb rule, a sub basin should have 1- 10 HRUs. HRU definition allows users to load land use land cover map, soil map and it also include classification of HRU for different slope classes, which has linked to the SWAT database to generate HRUs. The inserted datasets have reclassified according to the given codes. The slope map is classified in four different ranges, which varies from 0-10, 10-15, 15-30, 30-60,60-9999 in percentage. To calculate an acceptable numbers of HRUs of each and every sub basins, a correct combination of land use land cover, slope and soil (15%, 22%, and 115%) were used. The associated topographic report regarding HRUs has been generated successfully which described all the statistical parameters for each sub basins like minimum elevation, maximum elevation, standard deviation, percentage of area, percentage of watershed. The land use map as well as soil map have been overlapped by 100% with the delineation of watershed and 42 HRUs were created for the 5 sub basins. The slope map is shown Fig no.7

Figure7*:Map showing sub basins and outlet of the Govindpur watershed*



Source*: Own Draft*

5.2.5 WGN files and Write Input Tables

SWAT requires weather data inputs; those are daily precipitation, maximum/minimum temperature, solar radiation, wind speed and relative humidity. Values for all these climatic parameters may be determined from previous records of observed data or they may be generated as required. Required parameters have been used in SWAT weather input database, with swat supported format and inserted into the model. Three weather stations are defined across the river basin. The weather generator input file consists of statistical data, needed to create representative daily weather data for every sub basins. It is Ideal to take at least 20 years of recorded data are used Stream Flow Modeling a part of Subarnarekha Basin using to generate parameters for preparing the .wgn file. For this current study 21 years of data is used. These statistics has been generated using WGN EXCEL MACRO downloaded from SWAT website. The weather generated input file consists of several parameters like TITLE (the first line of the .wgn file is used for user comments), WLATITUDE (latitude of weather stations used to calculate statistical parameters), WLONGITUDE (longitude of the weather stations), WELEV (elevation of the weather stations), RAIN_YRS (the number of years of rainfall, if no value is input for RAIN_YRS, SWAT will set 10, by default), TMPMX (average or mean daily maximum air temperature), TMPMN (average or mean daily minimum temperature), TMPSTDMX (standard deviation for daily maximum air temperature), TMPSTDMN (standard deviation for daily minimum air temperature), PCPMM (average or mean total monthly precipitation), PCPSTD (standard deviation for daily precipitation in month), PCPSKW (skew coefficient for daily precipitation in month), PR_W (probability of a wet day following a wet day in the month), PCPD (average number of days of precipitation in month), RAINHHMX (maximum 0.5 hour rainfall in entire period of record for month), SOLARAV (average daily solar radiation for month), DEWPT (average daily dew point temperature for each month or relative humidity can be input), WNDAV (average daily wind speed in month).

3.2.6 Edit SWAT Input

The modeler can edit the database file in the model. The climate data like precipitation, relative humidity, solar radiation, wind speed, temperature and location of meteorological data file were used as inputs for running the SWAT model. The required files were developed as per the format given in the input/output documentation of SWAT 2009.

5.2.7 SWAT Simulation

Once all the weather parameters are inserted in the model, SWAT has been run successfully. The output of the model like HRU, RCH, and SUB was generated on the daily basis. The simulated discharge and its associated reports were generated successfully.

5.3 SWAT CUP Model (Sufi-2)

SWAT-CUP was used for calibration and validation purpose. After SWAT simulation SWAT-CUP 5.1.6.2 (2012) was used to calibrate and validate the data using SUFI-2 algorithm. In the SWAT-CUP, observed stream flow and SWAT simulated data (1995 -2004 for calibration) was imported to run the model, both datasets were prepared as per the required format in the SWAT-CUP. Data for the first two year (1993-1994) were conserved as 'warm-up' period for model initialization. Same methods were followed for model validation (1995-2013). The model iteration was 500 for both calibration and validation. The statistics (PBIAS, R2, NSE, p-value, t-test) for calibration was evaluated for the period.

6. RESULTS AND DISSCUSSION

According to the objectives of this study, the study area Govindpur watershed of Subarnarekha River is delineated from the Arc SWAT automatically. Various input layers are prepared from satellite images, digital elevation model, toposheet and weather data. Data base has been made following the requirement of the Arc SWAT model. The hydrological datasets like rainfall, temperature, relative humidity, solar radiation, and wind speed have been used. The model has performed on daily basis for surface discharge simulation. To improve the result of simulation calibration process is done. The calibrated output is used to validate for further years. And lastly the observed and simulated stream flow data has been compared.

6.1 Model Simulation

All the primary data sets are used as inputs in Arc Swat to get the value of discharge. Model takes into account topographical data, soil data, land use land cover data and climatic parameters. Finally it gives the result of discharge. The model result for the Govindpur watershed is accurate by 34%, as the regression value of observed discharge data from India-WRIS and model calculated data is 0.339.Simulation is done for the year 1993 to 2004.

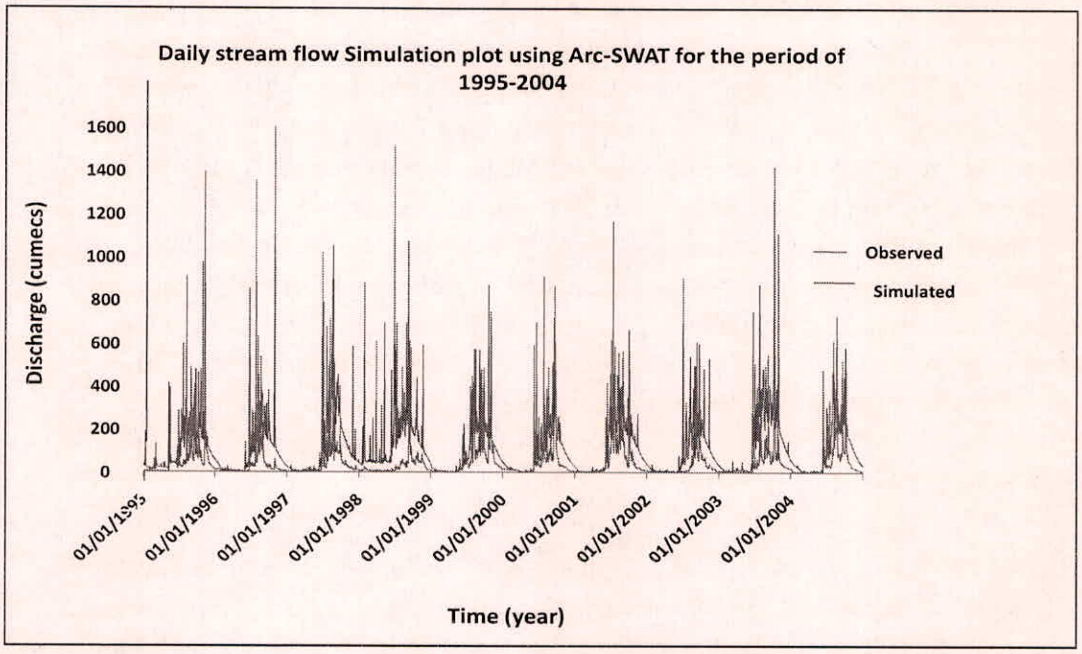


Figure 8: Graph showing the relation between observed and simulated stream flow

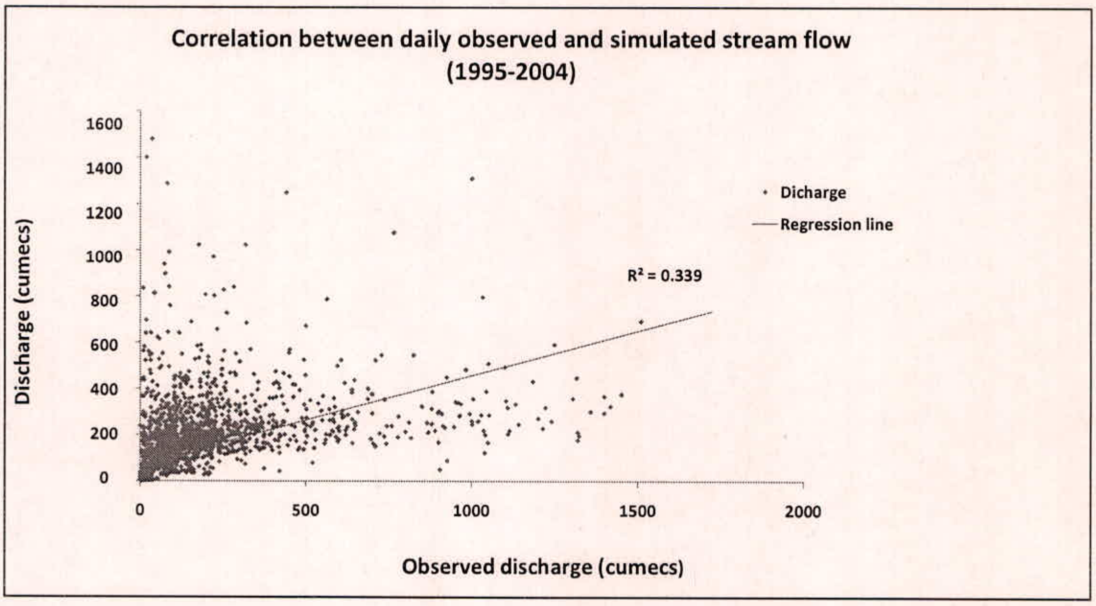


Figure 9: Graph showing Correlation between daily observed and simulated stream flow (1995-2004)

6.2 Model Calibration

The calibration has performed for the year of 1995 to 2005 using discharge data recorded at the outlet of the study area which is Govindpur, in which two years are taken as a "warm-up period". Model validation was done for the catchment using SUFI-2 algorithm, which is available inside the SWAT-CUP software. The model is calibrated based on several parameters like available water content (AWC) and soil evaporation compensation factor (ESCO) and some others, in between the range of the model. Many simulations have been conducted till the time the desired simulated flow was obtained. In order to check the efficiency of the model, the simulated and observed discharge value have been compared with coefficient of determination (R^2) and Nash Sutcliffe efficiency index (NS) were applied. The time series of observed and simulated discharge value have been compared graphically on the daily basis. The calibration period denoted the coefficient of determination (R^2) of 0.524 (Fig no.11) for daily results. The time series of observed and simulated daily discharge are shown in Fig no.10respectively.

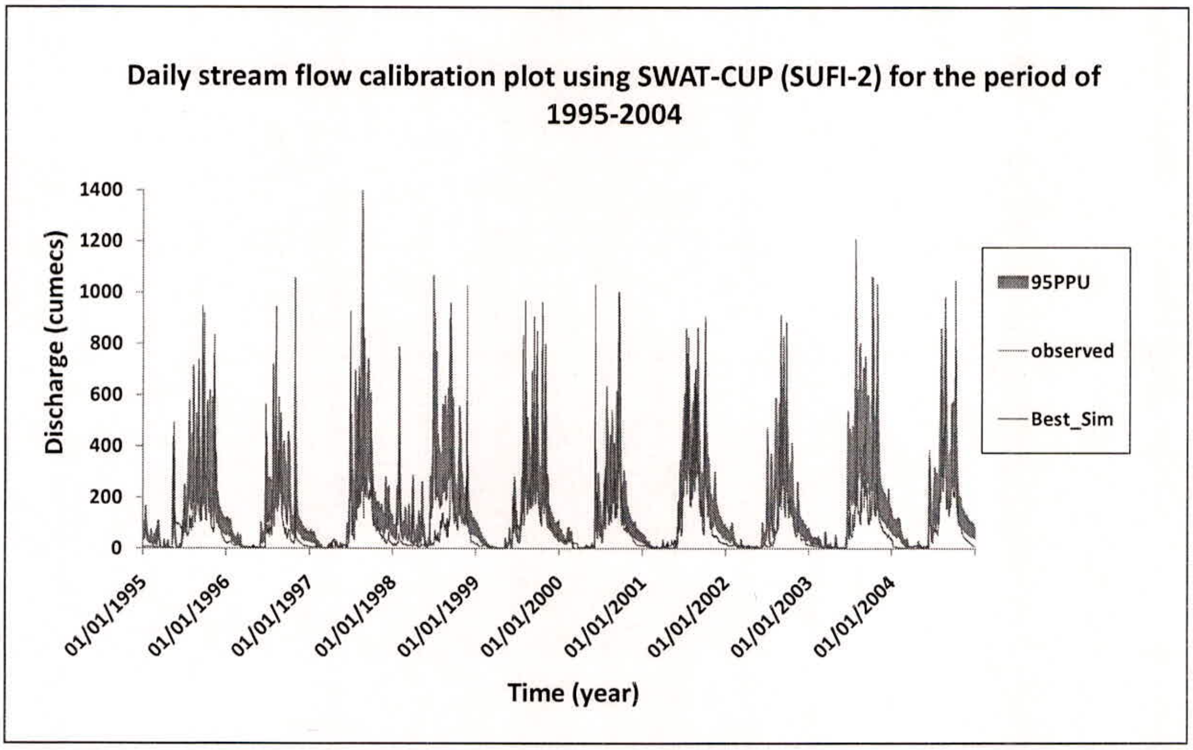


***Figure 10**: Graph Showing Daily flow calibration plot using SWAT-CUP (SUFI-2) for the period of 1995-2004*

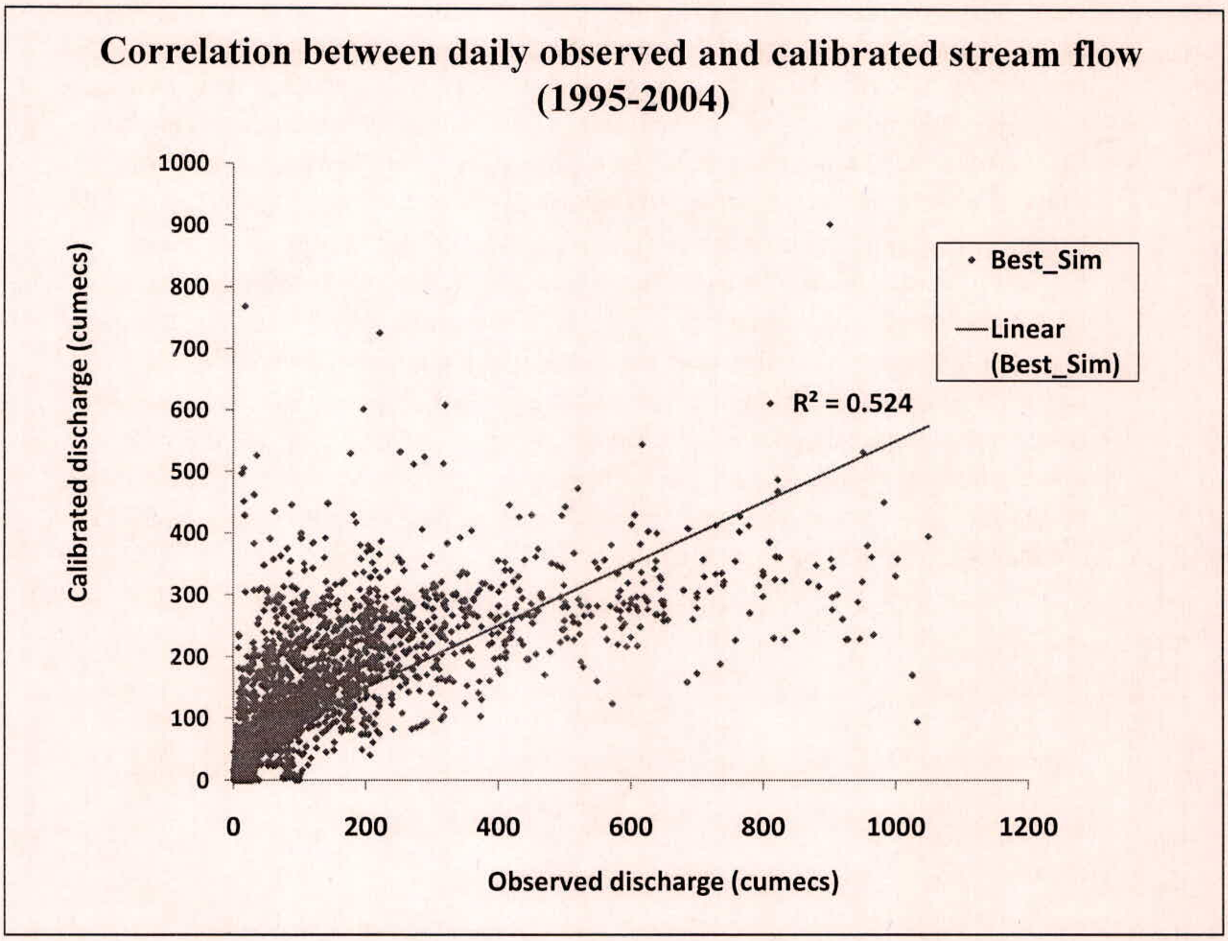


***Figure 11**: Correlation between daily observed and calibrated stream flow for the period of (1995-2004)*

6.2 Model Validation

According to the result of calibration the sensitive parameters are found, the model was validated for the daily surface runoff (Fig no.12 & 13) from 2005 to 2013. After achieving the objective function for calibration, validation of the model is followed. Validation process is similar to calibration procedure. It is important to note that the climatic dataset used for calibration process is different from the dataset used for validation process. If the objective could not be achieved for the validation datasets, calibration process for model assumptions need to be revisited (White and Chaubey, 2005). Iteration was run in several times until the calibration goal was achieved. For these current study iteration carried out 23 times. For each iteration around 400-600 simulation were performed. The model is simulated at the outlet (Govindpur). Model validation was done for the catchment using SUFI-2 algorithm, which is available inside the SWAT-CUP software. The simulated daily flow shows a satisfactory result. Table no.6 is shown the statistical performance for calibration and validation of the model.

Table no 6. *Statistical evaluation during calibration and validation period*

Model Stages	**Evaluation Statistics**				
	R	R^2	NS	P-factor	R-factor
Simulation	0.58	0.339	-	-	-
Calibration	0.72	0.524	0.51	0.11	0.02
Validation	0.70	0.49	0.48	0.69	0.45

Source: *Own Draft*

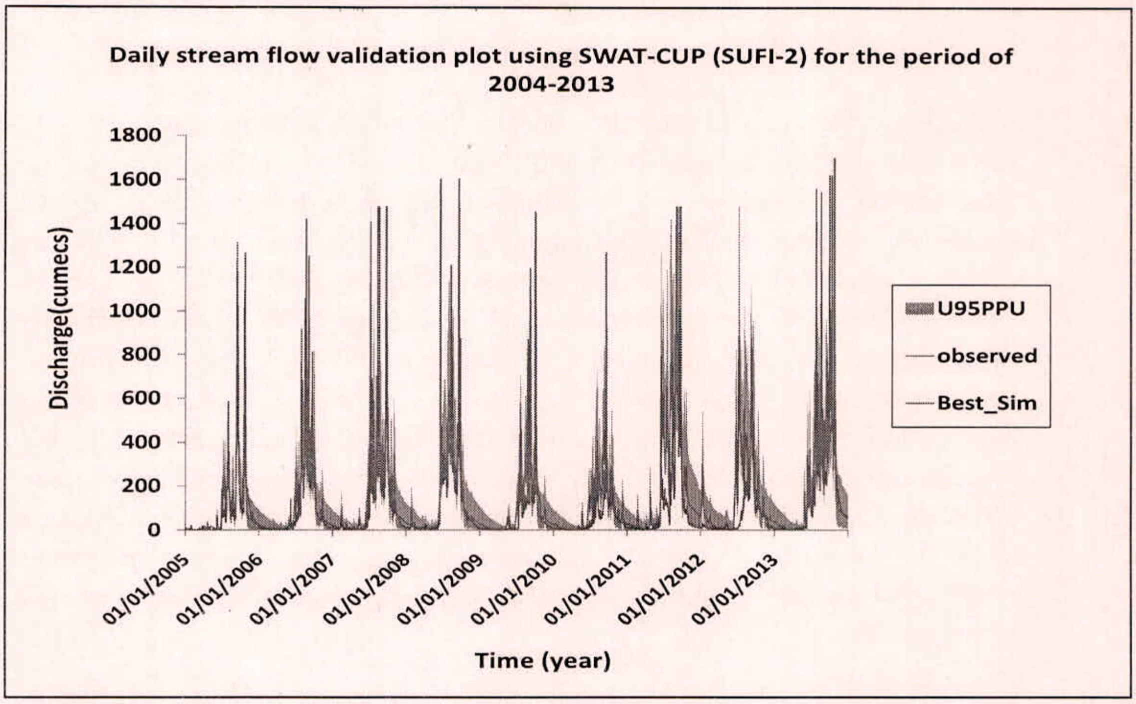


***Figure 12**: Daily flow validation plot using SWAT-CUP (SUFI-2) for the period of 2005-2013*

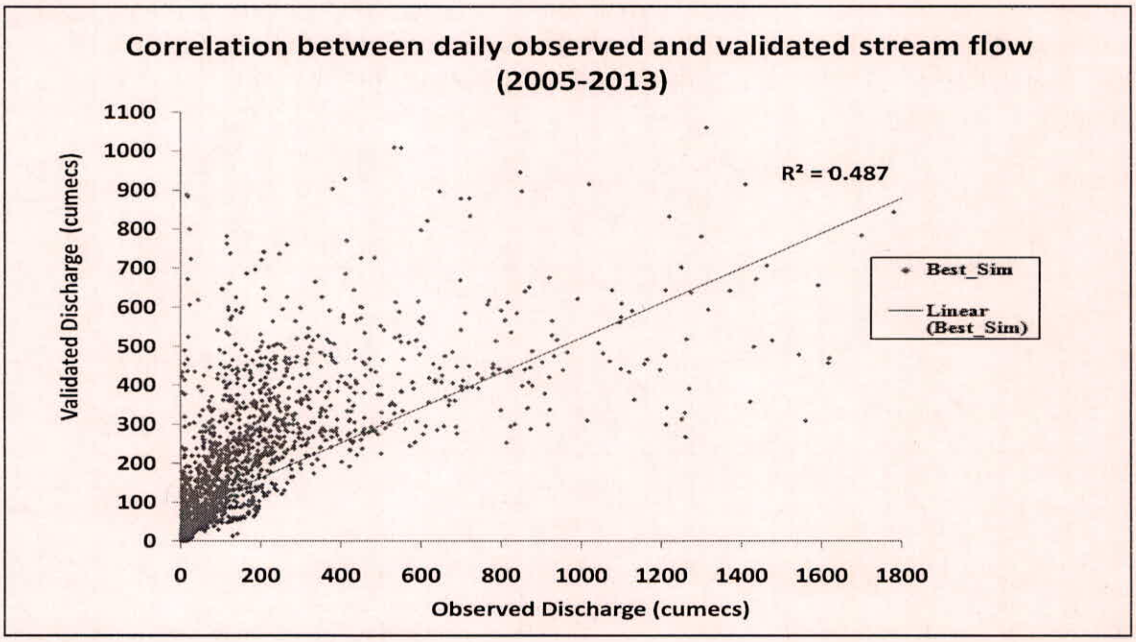


***Figure 13**: Correlation between daily observed and validated stream flow for the period of 2005-2013)*

6.3 Global Sensitivity Analysis

Before applying the calibration technique, a sensitivity analysis has performed for the delineated Govindpur watershed, a large number of parameters have played a great role. In SWAT-CUP, SUFI-2 it is needed to find out the key parameters that affect the runoff. Global sensitivity analysis is done to determine the sensitive parameters in the study. Two statistical tests have been measured to find out the sensitivity of the selected parameters namely p-value and t-stat. The t-stat measures the sensitivity of a parameter, on the other side p-values gives a measure of significance of sensitivity. The parameters were used to rank according to their sensitivity which influence of stream flow. The parameters are differ from one basin to another basin based on their geomorphology, therefore cannot accept any generalization status for sensitivity analysis for model calibration (Gyamfi et al. 2015). The most sensitive parameters listed in Table no.6 The SUFI-2 algorithm is in built within the SWAT calibration and SWAT-CUP environment. In SUFI-2 the goodness of calibration is measured on the basis of closeness of the p-value towards 0 and the t-stat towards positive values. The number of iteration is necessary to get the best threshold of the parameter in the simulation result (Singh et al, 2013). In the study however the efficiency has been measured including several statistical techniques likewise Nash-Sutcliffe (NS) [Equation number 1], the coefficient of determination (R^2) [Equation number 2] and some other also. Percent bias (PBIAS) [Equation number 3], and RMSE observation standard deviation ratio (RSR) [Equation number 4] have been used to justify the efficiency of the model.

1.

$$\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n}\left(Y_i^{obs} - Y^{obs,mean}\right)^2}$$

2.

$$R^2 = \left[\frac{\sum_{i=1}^{n}(O_i - S_i)(S_i - \bar{S})}{\left(\sum_{i=1}^{n}(O_i - \bar{O})^2\right)^{0.5}\left(\sum_{i=1}^{n}(S_i - \bar{S})^2\right)^{0.5}}\right]^2$$

3.

$$PBIAS = \frac{\sum_{i=1}^{n}(O_i - S_i)\times 100}{\sum_{i=1}^{n} O_i}$$

4.

$$RSR = \frac{\sqrt{\sum_{i=1}^{n}(O_i - S_i)^2}}{\sum_{i=1}^{n}\left(O_i - \bar{O}\right)^2}$$

Where Oi= observed variable, Si= simulated variable, O dash = mean of observed variable. S dash = mean of simulated variable, n = number of observation in the model. The result of sensitivity analysis of parameter using SUFI-2 method is shown in Table no. 7. For this current study eleven parameters have been used, five were found to be more sensitive to the stream flow depended on its t-test and p-value ($p < 0.00$). Sensitivity of a parameter is calculated based on the t-test, and significance of the parameter's sensitivity analysis is measured by p-value. A parameter with larger t-stats and smaller p-value considered as most sensitive parameter on the specific variable. The sensitivity of a parameter has been ranked based on the SCS runoff curve number (CN2) on the stream flow. The sensitivity of a parameter varies with respect to land use and soil properties of the specific area. The other relative sensitive parameters ranges from 0.00 to 0.78 according to p-value, the parameters are CN2 (SCS runoff curve number), SOIL_K (Saturated hydraulic conductivity), RCHRG_DP (Deep aquifer percolation fraction), CH_K2 (Manning's n value for the main channel), ALPHA_BF (Base flow alpha factor or recession constant), ALPHA_BNK (Base flow alpha factor for bank storage), ESCO (Soil evaporation compensation factor), GW_DELAY (Groundwater delay), SOL_AWC (Available soil water capacity), GW_REVAP (Groundwater "revap" coefficient), and GWQMN (Threshold depths of water in the shallow aquifer required for return flow to occur).

Table no 7. *List of Parameters used in SWAT Model for Sensitivity Analysis*

Parameters	Description	Units
Para meters governing surface water response		
CN2	SCS runoff curve number	none
ESCO	Soil evaporation compensation factor	none
SOL_AWC	Available soil water capacity	mm/mm
SOL_K	Saturated hydraulic conductivity	mm/h
Para meters governing surface water response		
GW_REVAP	Groundwater "revap" coefficient	none
RCHRG_DP	Deep aquifer percolation fraction	none
GWQMN	Threshold depths of water in the shallow aquifer required for return flow to occur	mm
GW_DELAY	Groundwater delay	days
ALPHA_BF	Base flow alpha factor or recession constant	days
ALPHA_BNK	Base flow alpha factor for bank storage	days
Para meters governing surface basin response		
CH_K2	Manning's n value for the main channel	mm/h

Source: *Own Draft*

The parameters ranges have been used to calibrate the model with help of SUFI- 2 method. For the study area eleven most sensitive parameters and their fitted value with ranking is defined in Table no. 8

Table no 8. *Eleven most sensitive parameters used in calibration of SWAT model*

Parameters	Rank	Maximum Value	Minimum Value	Fitted Value
CN2	1	-0.76	-0.77	-0.77
GWQMN	2	1.89	1.89	1.89
GW_DELAY	3	108.92	108.28	108.30
ALPHA_BF	4	0.42	0.42	0.42
GW_REVAP	5	0.21	0.19	0.19
ESCO	6	0.72	0.71	0.71
SOL_K	7	-0.31	-0.33	-0.32
CH_K2	8	166.95	165.85	166.88
SOL_AWC	9	0.63	0.63	0.63
RCHRG_DP	10	0.66	0.64	0.65
ALPHA_BNK	11	0.52	0.51	0.51

Source: *Own Draft*

6.4 p-value and t-stat

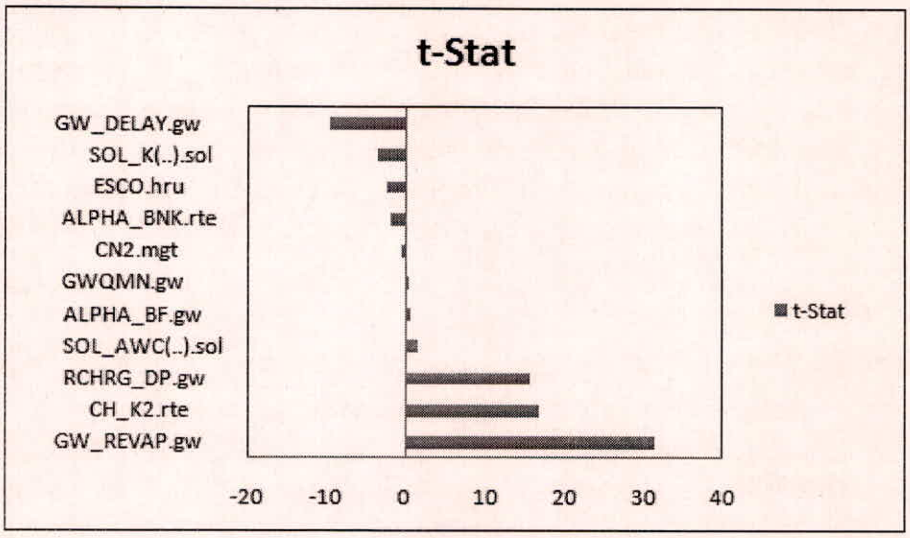
The *P* - value is defined as the probability, under the null hypothesis of obtaining a result equal to or more extreme than what was actually observed. P – value closer to zero means that parameters are more sensitive. Smaller the P - value, the larger the significance.At-Statistics is commonly used to determine whether the mean of a population significantly differs from the mean of another population. The t- Stat measures the size of the difference relative to the variation in your sample data. It can be either positive as well as negative.

***Table no 10**. Sensitivity ranking of parameters for modeling stream flow in the intermodal part of Subarnarekha River basin*

Parameter name	t-Stat	P-Value
CN2.mgt	0.64	0.52
GWQMN.gw	0.414	0.68
GW_DELAY.gw	-9.664	0.00
ALPHA_BF.gw	0.64	0.52
GW_REVAP.gw	31.414	0.00
SOL_K(..).sol	-3.62	0.00
CH_K2.rte	16.75	0.00
SOL_AWC(..).sol	1.49	0.14
RCHRG_DP.gw	15.70	0.00
ALPHA_BNK.rte	-1.87	0.06

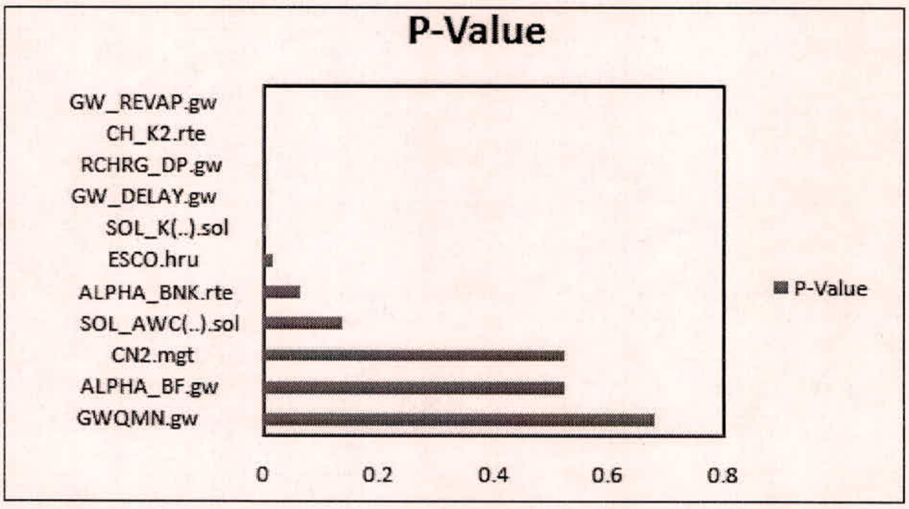
***Source:** Own Draft*

***Figure 14**: Graphical representation of t-test showing the sensitive parameters*



***Source:** Own Draft*

***Figure 15**: Graphical representation of p-value showing the sensitive parameters*

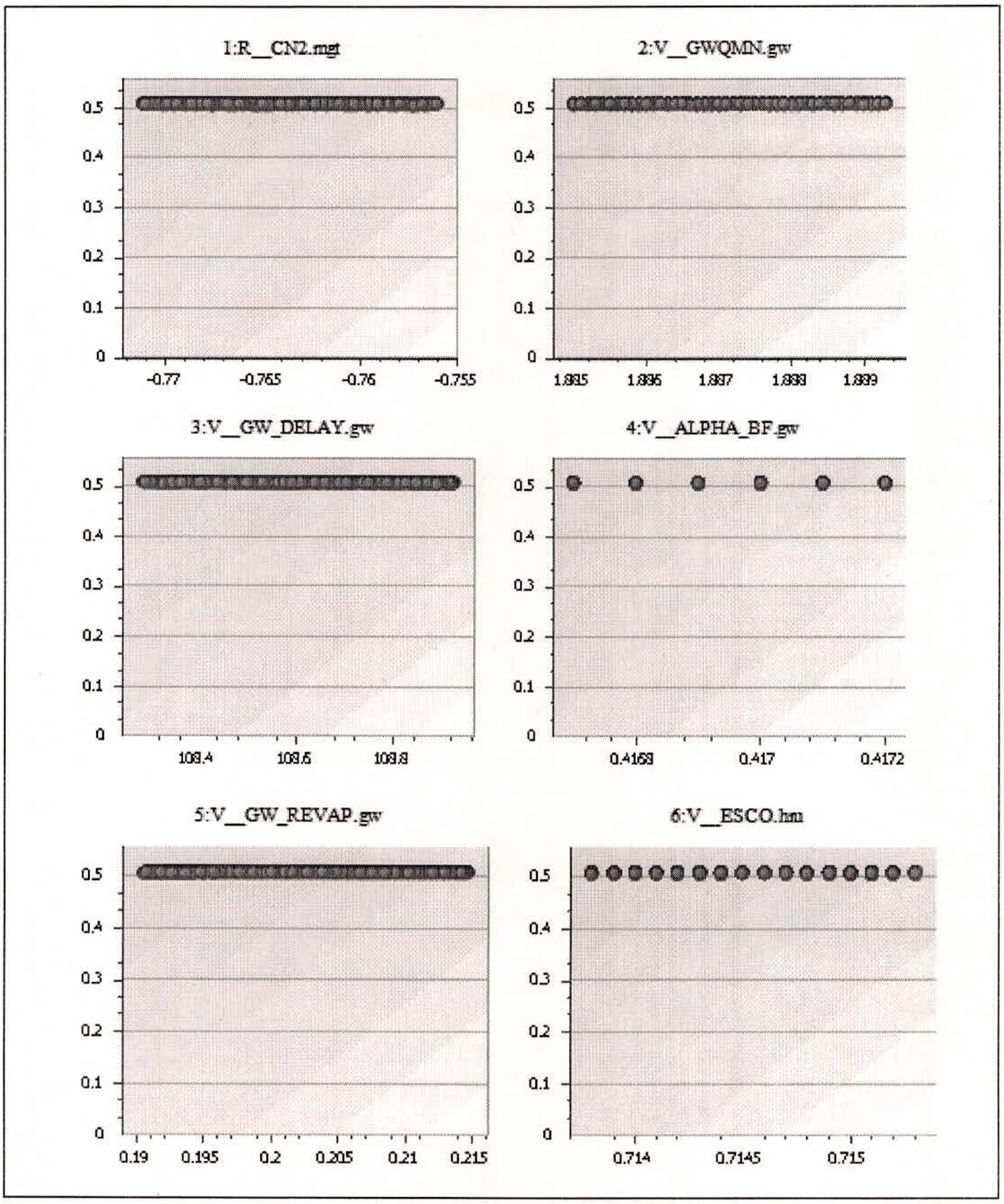


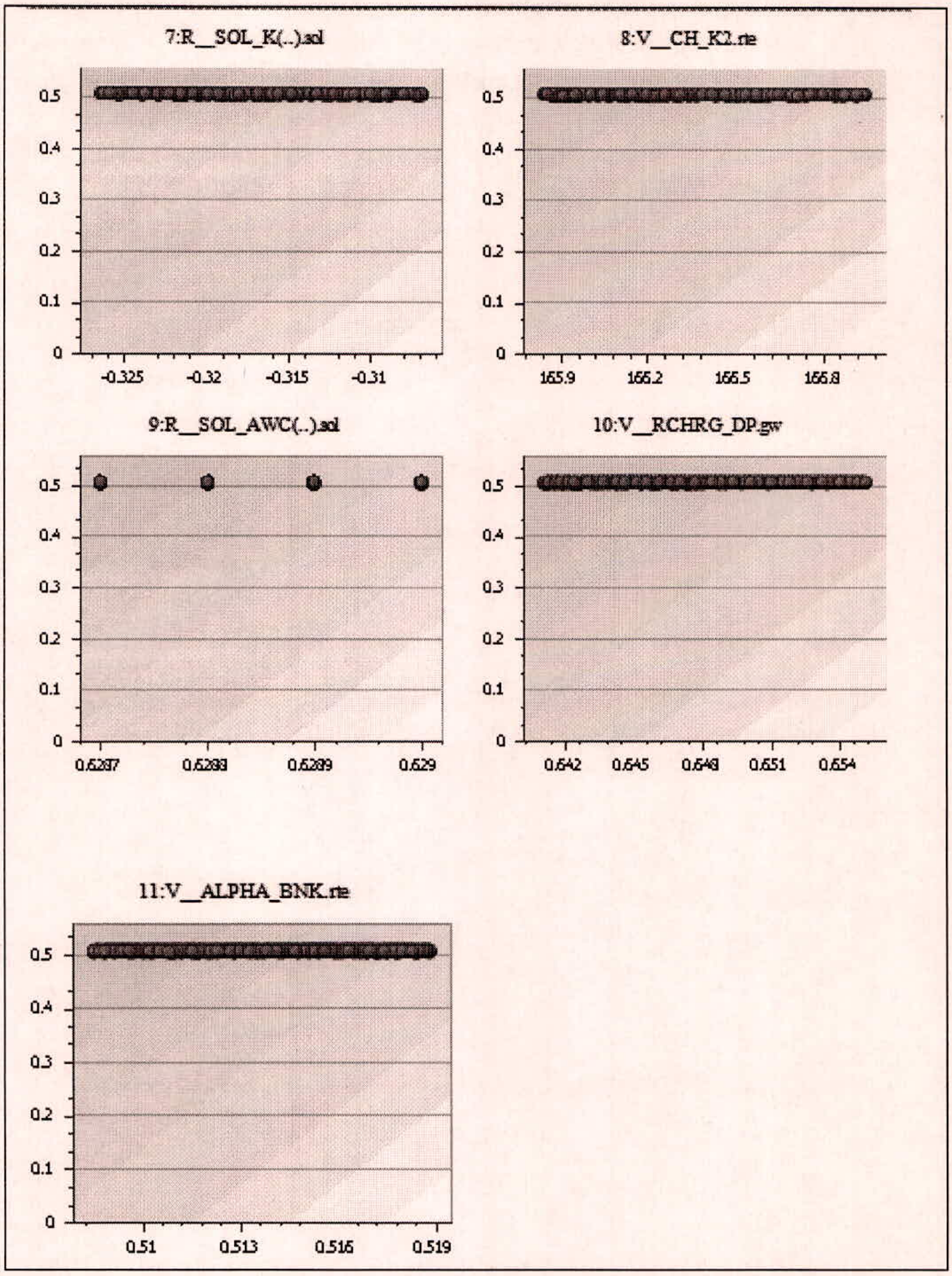
***Source:** Own Draft*

6.5 Dotty Plot

The dotty plots showing the distribution of the number of simulations in the sensitivity analysis after comparing the parameters value with the objective function for daily calibration. The mentioned graphs for the study area are shown in Fig no.16. It can be concluded that during calibration process, maximum parameters are less uncertainty than validation period.

***Figure 16**: Dotty Plots for the study area during calibration*





Source: *Own Draft*

6.6 Estimation of water balance for the Govindpur watershed

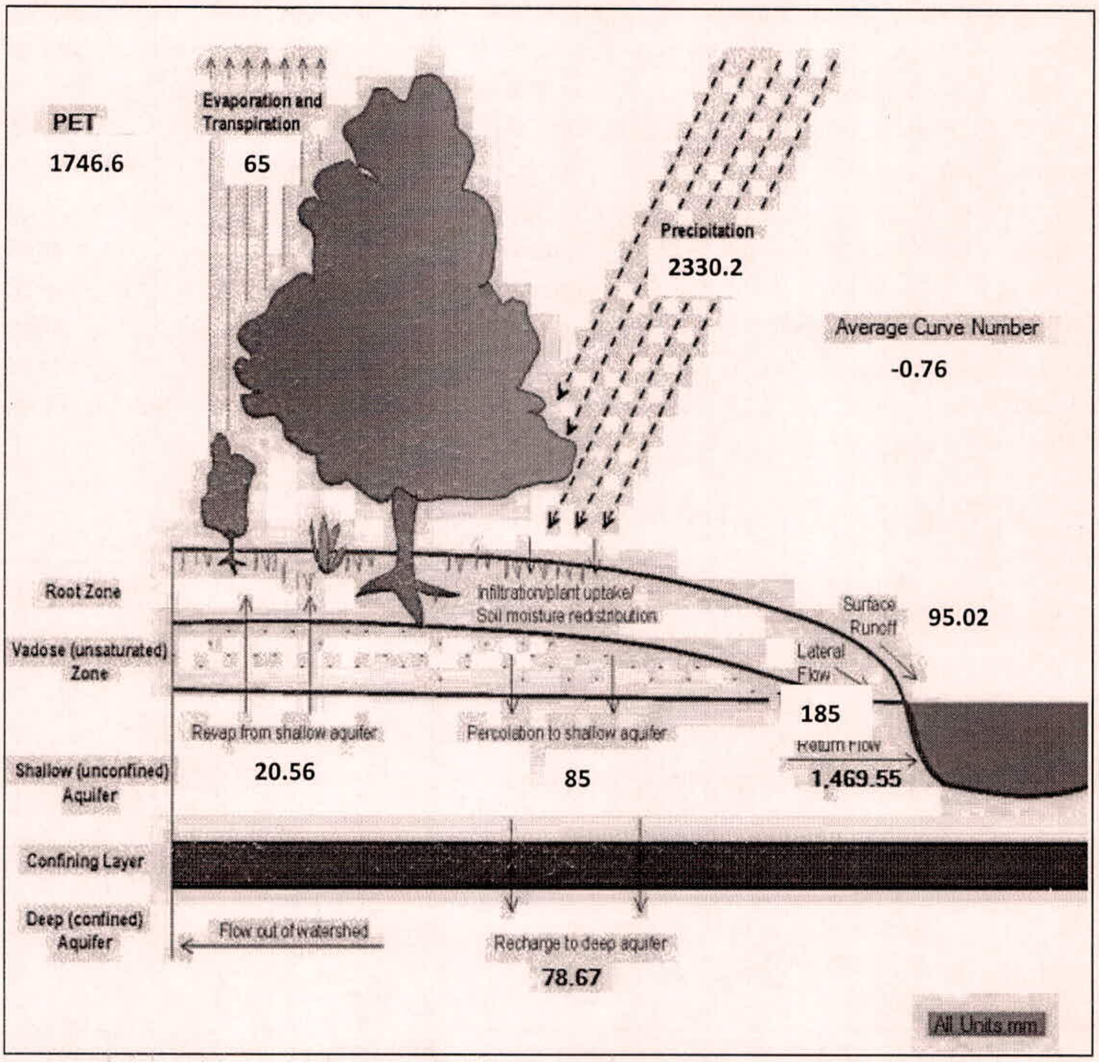
By using Arc SWAT, mean annual water balance for the study area (Fig no. 17) has been simulated for the year of 1993to 2013. After calibration the result is quite like this, the average observed discharge is 96.75 cumecs where the simulated discharge comes out 97.85 cumecs, which is much closer to the observed one. The water balance components for calibration and validation period are shown in Table no. 11. The process of SWAT simulation is depending on water balance equation. Where SWt is the final soil water content (mm H2O), $SWo$is the initial soil water content (mm H2O), t time in days, Rday amount of precipitation on day I (mm H2O), Qsurf the amount of surface runoff on day i (mm H2O), Ea the amount of evapotranspiration on day i (mm H2O), Wseep the amount of percolation and bypass existing in the soil profile bottom on day i(mm H2O), and Qgw is the amount of return flow on day i (mm H2O). The intermodal part of the Subarnarekha Basin (Govindpur watershed) receives 2330.2 mm precipitation annually out of this 65 mm takes place in evapotranspiration process. The SWAT simulated mean water yield is 543.31 mm, only this water is useful for drinking and irrigation purposes. The water budget components are shown in table no. 11.

Table no. 11 *showing the annual water balance for the study area*

Annual Basin	Calibration (Parameters)	Validation (Parameters)
PRECIP	2330.2 mm	2295.3mm
SURFACE RUNOFF Q	2.90mm	1.90mm
LATERAL SOIL Q	405 mm	488.68 mm
GROUNDWATER (SHALAQ) Q	283.85 mm	79.65mm
DEEP AQ RECHARGE	995.35mm	1166.88mm
TOTAL AQ RECHARGE	1519.37 mm	1633.19 mm
TOTAL WATER YLD	543.31 mm	570.17mm
ET	403.5mm	389.8 mm

Source: *Own Draft*

***Figure 17**: Pictorial diagram of water balance by SWAT Check*



***Source:** Own Draft*

7. SUMMARY AND CONCLUSIONS

In the present work, the main objective was to simulate stream flow for a part of Subarnarekha River basin using SWAT model, an extension of Arc GIS. SWAT-CUP is one of the latest programs available for calibration, validation and uncertainty analysis of SWAT model. This effective graphical interface allows generating outputs, to compare simulated data with observed data. SUFI-2 is one of the procedures in SWAT-CUP which is effective but needs so many iterations as well as modification of the parameters ranges for better results. These methods are flexible allowing users to adopt different measures and objective functions. SUFI-2 methods have been used in the present study. Sensitivity analysis shows the most sensitive parameters for the simulation of stream flow including CN2, SOIL_K, RCHRG_DP, CH_K2, ALPHA_BF, ESCO, GW_DELAY, SOL_AWC, GW_REVAP, ALPHA_BNK and GWQMN. SWAT model has been calibrated and validated using SWAT CUP, Sufi-2 software to examine its applicability for simulating daily basis data. For this study the model set up has been arranged for 21 years (1993-2013), the first two years were considered as the warm up period of the model. Out of these 21 years, 12 years (1993-2004, including warm up period) were used for calibration and next 9 years (2005-2013) for validation of model. As a simulation output the coefficient of determination (R2) and Nash–Sutcliffe (NS) were mainly used for performance evaluation. The model simulated the daily runoff of the catchment with a moderate degree of satisfaction with R^2, R2, NS as 0.72, 0.52, 0.49 during calibration and 0.70, 0.49 and 0.48 respectively during validation. Though the picks of the graphs not matched very well, the matching of observed and simulated data is found to be good up to some extent. In SWAT MODEL SWAT Check is also a good option for water balance calculation and for the calculation of parameters like evapotranspiration, precipitation, average curve number, surface flow, lateral flow, percolation to shallow aquifer, and recharge to deep aquifer. SWAT check presenting all these parameters in a pictorial manner.

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Learning

- ## Work experience:

Work experience is very good. Though as an intern, but it is the first time when I am working somewhere and first time ever being a member in Water Resource department of National Institute. The office atmosphere makes a good habit of time maintaining, timely submitting works and built up the responsibility of completing your own project at your own responsibility.

- ## Academic and scientific and experience

The best part of this journey is when I joined as an intern my supervisor Dr Sarad Kumar Jain was the head of Water Resource Department and few months letter he became the director of National Institute of Hydrology, so I really feel myself very lucky to work with him. First time work with such a great scientist, such a knowledgeable person still noble, humble and wise, he managed to get time from his very busy schedule to discuss my work and my official problems. Not only him other scientists are also so helpful that I never fill shy to ask them any question regarding to my work

As a student of Geoinformatics I had a very less knowledge of Water Resource when I came here, but after working here now I am aware of basics of Hydrology at some extent.

- ## Social and cultural experience

The best thing I feel here that one can work very smoothly in a National Institute without being very fluent in spoken English. The main thing is the eager to know something; language is not a barrier for learning. If the person in front of you is aware of your interest of learning he will definitely help you to acquire knowledge.

People are very helpful here, not stubborn with religion or language.

From the point of cultural experience I experienced both the "Dawat" in Eid and

"Kawad yatra"(carnival from Roorkee to Haridwar in the month of "sravan").